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TRSB MICROWAVE LANDING SYSTEM DEMONSTRATION PROGRAM AT TONCONTI--ETC(U)
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TRSB MICROWAVE LANDING SYSTEM DEMONSTRATION PROGRAM AT TONCONTIN INTERNATIONAL AIRPORT TEGUCIGALPA, HONDURAS.

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U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D.C. 20590

240 550

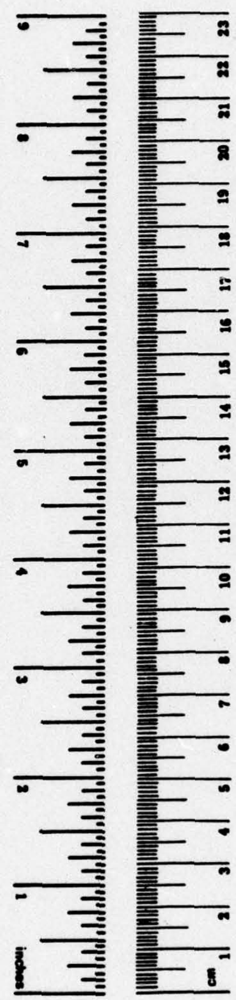
NOTICE

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

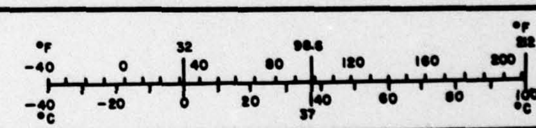
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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deg

16. Abstract

The FAA is conducting operational demonstrations of several TRSB hardware configurations at selected airports in the United States and abroad. The first demonstration was at Cape May, New Jersey, using the Small Community System. The second demonstration was at Jorge Newbery Aeroparque in Buenos Aires, Argentina.

The third demonstration, using the Small Community System at Toncontin Airport in Honduras, presented a geographical challenge to the operation of any precision landing system. Mountainous terrain and minimal NAV-AIDS and runway lights, limit scheduled airline flights to daylight hours. Terrain features necessitated offset approach paths for Runway 19, with azimuth and elevation sites collocated. deg

This TRSB configuration provides azimuth proportional guidance ±10 degrees about the runway centerline, with directional guidance from 10 degrees out to 40 degrees. Elevation proportional guidance from 2 degrees to 11 degrees, with fly-down clearance from 11 degrees to 15 degrees, is provided. Coverage distance is at least 20 nautical miles under heavy rain. deg

Flights in the NAFEC CV-580 demonstrated three approaches: (1) Parallel to runway centerline, offset by 58.5 meters with 4.5 degrees elevation angle; (2) 3 degrees azimuth radial with 4 degrees elevation angle; and (3) 9 degrees azimuth radial with 3.5 degrees elevation angle. In all cases, decision height was 123 meters (400 feet).

Results using the TRSB System are: (1) The system required minimal site preparation and installation time; (2) demonstrations of several offset approach angles indicated TRSB guidance flexibility; (3) the TRSB system was judged subjectively as providing excellent guidance signals; (4) the TRSB "Small Community System" was demonstrated to meet its design specifications; and (5) for this airport and runway, the data indicates that guidance signal quality, with no filtering, is well within ICAO noise requirements for a "reduced capability system."

17. Key Words	18. Distribution Statement
Honduras TRSB MLS Small Community System	Document is available to U.S. public through the National Technical Information Service, Springfield, Virginia 22161

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Unclassified	Unclassified	38	

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INTRODUCTION

During the past several years, extensive engineering evaluation and flight testing has been accomplished on Time Reference Scanning Beam (TRSB) Microwave Landing System (MLS) equipments at the Federal Aviation Administration's (FAA) National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey, and at the Auxiliary Naval Landing Field, Crows Landing, California. TRSB MLS is the United States and Australian candidate submission to ICAO as the replacement for ILS.

In March 1977, the ICAO All Weather Operations Panel (AWOP) recommended TRSB to the Air Navigation Commission (ANC) as the preferred candidate system for international adoption. This decision by AWOP followed a 15 month period of intensive and comprehensive assessment of all competing microwave landing systems conducted by a working group of international experts under the sponsorship of the AWOP. The ANC forwarded the AWOP recommendation to the ICAO Council, whereupon the Council has scheduled a worldwide meeting for April 1978, to address the question of selecting the new international standard for an approach and landing system to replace ILS. Meanwhile, the Council has encouraged proposing States to conduct demonstration and flight trials at operational airports. Accordingly, the FAA has developed a program to conduct operational demonstrations of several TRSB hardware configurations at selected airports in the United States and abroad. These demonstrations are intended to show that TRSB is a mature system that meets the full range of requirements from general aviation use to scheduled air carrier operations, for Category I to Category III autoland, under good or poor airport siting conditions, and under extreme weather conditions. Additionally, these demonstrations provide opportunities for representatives and officials of the international aviation community to gain first hand knowledge of TRSB MLS, and assess its applicability to their particular requirements.

The first operational demonstration of TRSB away from NAFEC was conducted at a small community airport in Cape May, New Jersey. At the invitation of the Organization of American States (OAS) and the Argentine Government, the second demonstration was conducted at Jorge Newbery Aeroparque in Buenos Aires during a meeting of the OAS Aeronautical Telecommunications Group. The third demonstration was conducted at Toncontin International Airport, Tegucigalpa, Honduras, through arrangements made with the Government of Honduras and the Corporacion Centroamericana de Servicos de Navegacion Aerea (COCESNA) for a TRSB MLS demonstration November 24, 25, 1977.

COCESNA is a corporation set up by the Central American states of Costa Rica, Honduras, Nicaragua, Guatemala, and San Salvador, to operate and maintain communications and navigation facilities for the aviation community.

Tegucigalpa, the capital city of Honduras, is served by Toncontin Airport which has one runway 01/19, 1800 meters long (5900 feet) and 45 meters wide (148 feet). The runway starts at the airport boundary at the base of a mountain, and ends at the edge of a steep 31 meter (100 feet) drop. A plan view of the runway is shown in Figure 1. The airport has runway lights and a VOR-DME-NDB nearby, but has no other navigation aids or approach lights. The general topology of the surrounding countryside is mountainous. Two airlines, TAN and SAHSA serve Toncontin Airport with daily Boeing B-737 international flights, Convair CV-580 and Lockheed Electra domestic and international flights. All airline flights are scheduled for daylight hours with the air traffic tower operating between the hours of 0600 and 1800. This site represents a distinct geographical challenge to the operation of any precision landing system.

DISCUSSION

The TRSB system configuration selected for installation in Honduras was the "Small Community System" which had previously been demonstrated at Cape May County Airport in a split site configuration. This equipment was manufactured by the Bendix Corporation's Communications Division, in accordance with FAA specifications (see Table 1). It is the most economical system configuration, and was designed to provide azimuth proportional guidance over an area of plus and minus 10 degrees about runway centerline, with directional guidance (i. e., fly left or right from 10 degrees out to 40 degrees similar to an ILS localizer. The elevation proportional guidance extends from 2 degrees to 11 degrees. Fly-down clearance is provided from the upper limit of proportional guidance (11°) to 15 degrees. System coverage distance is at least 20 nautical miles under heavy rain conditions, and much greater under less stringent environmental conditions. The small community TRSB was designed to provide Category I operational minimums on most runways in most airport environments. Guidance quality, however, has been shown to be better than ILS, and will support autoland operations. General information on TRSB is presented in the Appendix to this document.

Initial Site Selection

On November 1, 1977, a two man team from the FAA arrived in Honduras to conduct initial discussions and perform a preliminary survey of prospective demonstration sites. Airports at both Tegucigalpa and San Pedro Sula were investigated, but the San Pedro Sula site was rejected because it is situated on relatively flat terrain and offered no particular challenge in the demonstration program.

Site Survey

After the decision on the site, an advance team was sent to Tegucigalpa on November 13, 1977, to conduct a detailed site survey at the airport. The normal MLS antenna sites relative to the runway were surveyed at both ends of Runway 01-19. Runway 01, which is the active runway about 80 percent of the time due to wind conditions, is served by a VOR/DME approach with 1200 feet/3 mile minimums. The approach plate is shown in Figure 2.

The elevation profile for the approach to Runway 01 is shown in Figure 3. As can be seen, a hill starts to rise steeply beginning at the overrun area (which is 63 meters long). From the prospective elevation antenna location for Runway 01 (approximately 200 meters from the threshold of 01), the hill presents an elevation profile of about 4.3 degrees. Allowing for terrain clearance of 1.1 degrees (as defined by TERPS), a descent angle of 5.4 degrees would be required. This was considered operationally unacceptable, and no further consideration was given to installing the system to serve Runway 01.

The site survey team next considered Runway 19. The elevation profile of this runway is shown in Figure 4, and a photograph is shown in Figure 5, looking toward the approach end of Runway 19 from a vantage point off Runway 01. Again, from the prospective elevation site for Runway 19, the highest point on the approach presents an elevation profile of about 3.3 degrees. Allowing for a 1.1 degree obstruction clearance, an approach elevation angle of 4.4 degrees would be required on centerline. However, as can be seen from the photograph in Figure 5, the hill slopes off and a gap is created. By utilizing the multiple angle capability of the TRSB MLS, several approach paths could be created from this site. It was, therefore, decided to install the equipment to serve Runway 19.

Exact site locations were next determined. Again, as can be seen from the photograph in Figure 5, the overrun area at the stop end of Runway 19

is small (63 meters long) and is utilized by aircraft departing on Runway 01 to gain maximum length available. The end of the overrun constitutes the airport boundary, and a public road crosses in the foreground of Figure 5. It was, therefore, impossible to place the azimuth antenna on the extended runway centerline of Runway 19 within the airport boundary, so an offset was necessary.

Two types of offset installations were considered. The first involved placing the offset azimuth at the far end of the runway. The second would have placed the azimuth at or near the approach end of Runway 19. The merits of both sites were assessed relative to the desired approach paths for Runway 19.

Figure 6 presents the terrain clearance angles for Runway 19 as a function of the angular deviation from runway centerline. It is obvious that lower elevation angles could insure adequate terrain clearance if offset approach paths were used. Figure 7 shows the aircraft maneuver requirements for an offset approach for the two types of azimuth site locations. With the azimuth offset at the far end of the runway, an "S" turn is required to stabilize on centerline after visual contact. The offset azimuth collocated with the elevation site offers a much smoother transition to the centerline. It was, therefore, decided to collocate azimuth and elevation sites. This siting offered the best solution to the limited airport boundary and the desirability of offset approach courses.

System Installation

The TRSB "Small Community System" arrived by air at Toncontin Airport in partial shipments over the period from November 19 to 21, 1977 (Figure 8). Because of time limitations, metal platforms made from 10 inch channel (25.4 centimeters) and 1/4 inch thick (0.64 centimeters) aluminum plates were used as mounting foundations instead of poured concrete (Figure 9). The monitor masts were also mounted on aluminum platforms. The installation process is depicted in Figure 10.

The TRSB azimuth and elevation subsystems were co-located as shown in Figure 11. As depicted in this diagram, the site was located 153.85 meters (500 feet) from threshold, with the azimuth equipment 58.46 meters (190 feet) from runway centerline. The elevation equipment location was 7.69 meters (25 feet) outboard from azimuth. All the electronics as well as respective antennae are integrated into the two housings as shown in Figure 12. The installation was such that the zero azimuth line for each

subsystem was skewed 3 degrees with respect to runway centerline. This insured that full CDI proportional guidance would be available when flying a 9 degree (with respect to centerline) radial through the mountain pass. System installation was completed, flight checked, and certified ready for use on the afternoon of November 22, 1977.

Operational Demonstrations

An FAA/NAFEC Convair CV-580 twin turbo-prop aircraft was the sole aircraft used for all flight demonstrations. Each demonstration flight consisted of three approaches, each starting at about 20 miles from threshold and terminating in a low approach or landing. The three approaches to Runway 19 selected for demonstration as depicted in Figure 13, were:

1. Parallel to runway centerline, offset by 58.46 meters (190 feet) with 4.5 degree elevation angle. Decision height of 123 meters (400 feet).

2. A 3.0 degree azimuth radial to runway centerline with 4.0 degree elevation angle. Decision height of 123 meters (400 feet) occurring before the runway centerline was intersected.

3. A 9.0 degree azimuth radial to runway centerline with 3.5 degree elevation angle. This approach was through a mountain pass. Again the decision height was 123 meters (400 feet) occurring before runway centerline was intersected.

During all approaches, the pilot flew under the hood until he reached decision height, then visual for a low approach or landing. A typical tracked approach is shown in Figure 14. On one occasion, the pilot flew under the hood to an altitude of 30.8 meters (100 feet) before going visual.

Government aviation officials in attendance at a COCESNA management meeting, Honduras civil and military aviation officials, airline pilots and officials, news media representatives, and other aviation minded individuals participated in the presentations and flight demonstrations conducted on November 24 and 25.

Operationally the TRSB "Small Community System" performed very well at this mountainous site. Signal guidance quality was judged to be excellent.

Performance Assessment

Ground based tracking for the TRSB demonstration flights was provided by an optical television tracker, manufactured by British Aircraft Corporation of Australia, designed to automatically track a light source on the aircraft and telemeter angular position back to the aircraft on a frequency of 126.25MHz. In the aircraft, the received tracker angle data was compared with TRSB angle data. The angle difference as well as tracker angle and TRSB angle were recorded on light sensitive strip chart recorder paper. The tracker alignment was such that for a given run, aircraft azimuth track or elevation track could be provided, but not both. On November 24, eight aircraft runs were tracked and recorded while on November 25, the number of tracked and recorded runs was six.

Figures 15, 16, 17, and 18 are copies of two azimuth and two elevation strip charts; one set of each conducted on 11/24/77, and 11/25/77. Each of these figures contains a reproduced trace of the optical tracker angle, the TRSB receiver angle, and the error between the two. The longitudinal axis of these plots represents range from Runway 19 threshold determined by a commissioned DME located approximately 1000 meters beyond the stop end of the runway. The expanded range increments appearing near the end of each run are due to the airborne recorder operator changing the recorder speed from 3 inches per minute to 12 inches per minute. The reproductions shown in these figures have been truncated prior to the threshold near the point representing the decision height for each run, because from that point on, the pilot flew the aircraft visually to touchdown.

Although it is possible to determine quantitative information from Figures 16 and 18 for elevation, the low sensitivity scale factor used for the azimuth runs presented in Figures 15 and 17, limit the precision of such measurements.

For the elevation runs, the total error, including bias and noise, does not exceed ± 0.1 degree. In most cases, the total peak-to-peak error was within ± 0.075 degrees. The elevation subsystem is well within its design specifications as well as the ICAO (AWOP) specification for a "reduced capability system." Over the range considered, the subsystem meets the ICAO (AWOP) guidance error specifications for a "full capability system," as well as the FAA proposed "TRSB Autoland" requirements.

For the azimuth runs, the small scale factor limits the analysis. However, some judgement can be made knowing that the granularity step apparent in the azimuth recordings is 0.04 degrees. Using this guide to interpret the scales, the peak-to-peak noise is approximately ± 0.075 degrees and generally somewhat smaller. The bias errors are typically 0.175 degrees due to a tracker offset compromise made to permit tracking of elevation and azimuth from this collocated site. Over the range considered, the azimuth subsystem is well within its design specifications, as well as the ICAO (AWOP) noise requirements for a "reduced capability system." Sensitivity of the azimuth recordings was not sufficient to make inferences with respect to the more stringent ICAO (AWOP) specifications for a "full capability system" or the FAA proposed "TRSB Autoland" requirements.

The system demonstrated its performance to be well within the "TRSB Small Community" design specifications and ICAO (AWOP) "reduced capability system" requirements.

Additional data will be published as a working paper to ICAO.

SUMMARY OF RESULTS

The TRSB system discussed in this document represents the most economical configuration of TRSB hardware thus far designed under the United States MLS development program, and within the FAA is referred to as the "Small Community System." Its design specification is equivalent to Category I ILS. In addition to its economical system architecture, the information presented herein indicates:

1. The TRSB system required minimal site preparation and installation time.

2. The TRSB system was installed in a collocated configuration providing guidance to a decision height of 400 feet, on a runway, representing a challenge to any precision guidance system, and where there was no precision guidance previously provided.

3. Demonstrations of several offset approach angles indicated TRSB guidance flexibility.

4. The TRSB system was judged subjectively as providing excellent guidance signals.

5. The TRSB "Small Community System" was demonstrated to meet its design specifications.

6. For this airport and runway, the data indicates that guidance signal quality, is well within ICAO noise requirements for a "reduced capability system."

TABLE 1'

TRSB ACCURACY, PHASE III SYSTEMS

			BIAS (DEG.)	PATH FOLLOWING NOISE (DEG.)	PATH FOLLOWING ERROR (DEG.)	CONTROL MOTION NOISE (DEG.)	REMARKS
Basic Narrow	AZ	SPEC	.19	.08	.2	.07	at 50' on 2.5° G/S
	EL	SPEC	.08	.09	.12	.05	
Small Community	AZ	SPEC	.29	.15	.33	.10	at 150' on 2.5° G/S
	EL	SPEC	.11	.12	.16	.10	

NOTES ON TRSB ALLOWABLE PFE DEGRADATIONS (PHASE III CONTRACTS)

	PFE Degradation W/Distance	W/Azimuth Angle	W/Elevation Angle
Basic Narrow			
Azimuth	None	Linearly to twice C/L error at ±60°	None to 9°. Linearly to 2 times from 9° to 20°
Elevation	Linearly to 1.5 times at 20 NM	None	Linearly to 3 times from 2.5° to 20°
Small Community			
Azimuth	Linearly to 0.4° at 20 NM	Linearly to twice C/L error at ±60°	None to 9°. Linearly to 2 times from 9° to 15°
Elevation	Linearly to 1.5 times at 20 NM	None	Linearly to 3 times from 2.5° to 15°

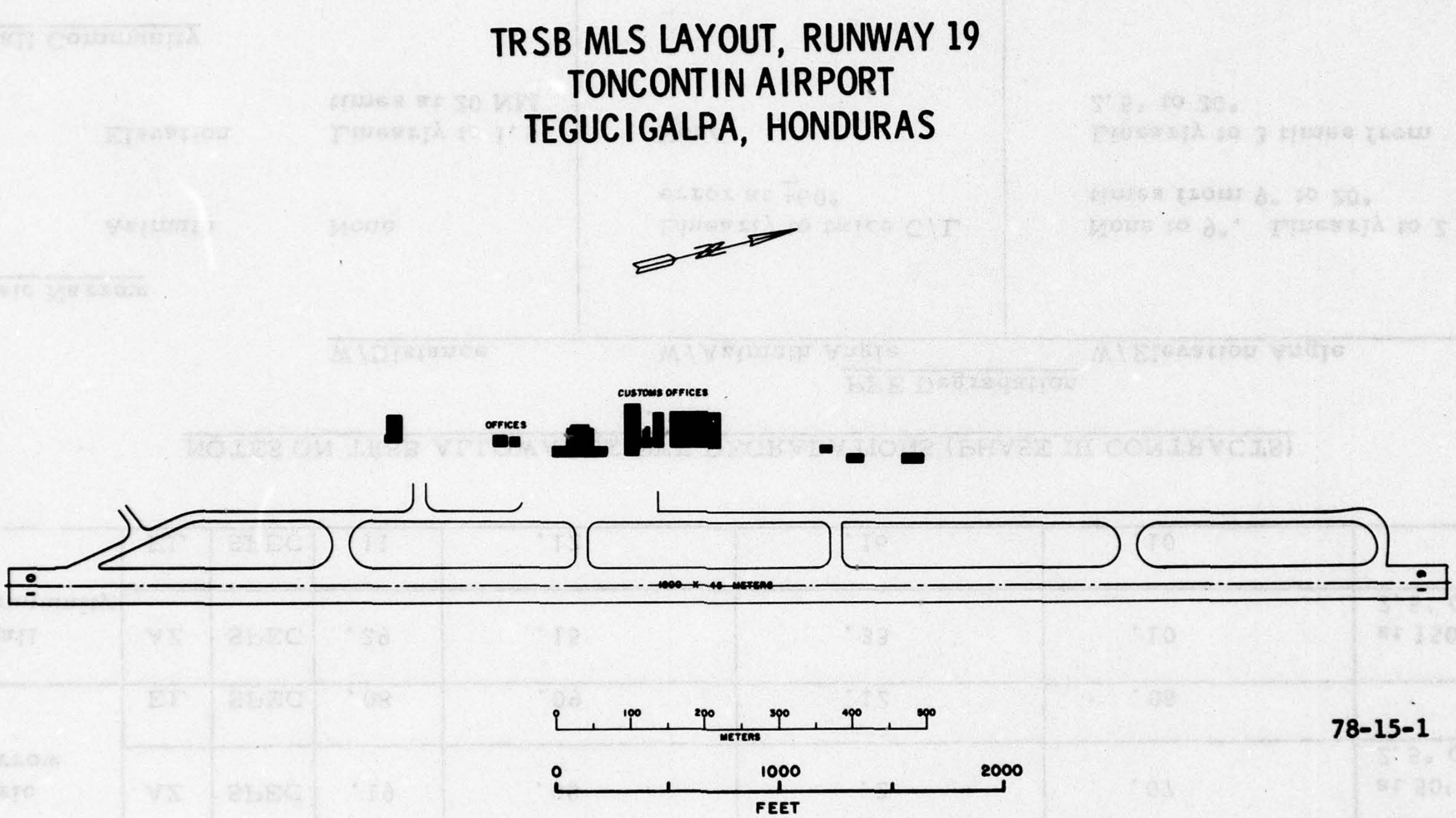
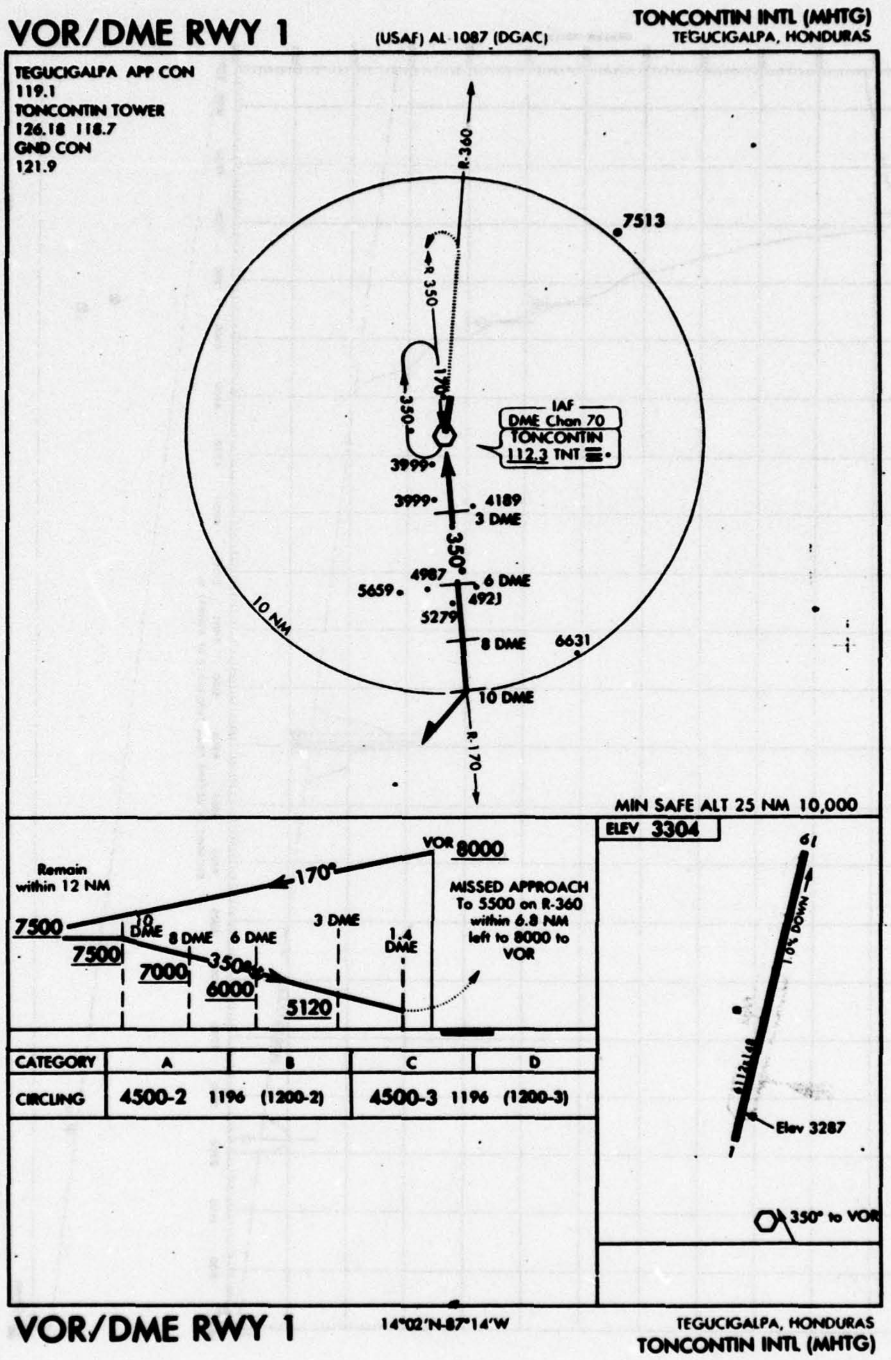


FIGURE 1. PLAN VIEW OF RUNWAY



CATEGORY	A	B	C	D
CIRCLING	4500-2	1196 (1200-2)	4500-3	1196 (1200-3)

FIGURE 2. RUNWAY APPROACH PLATE

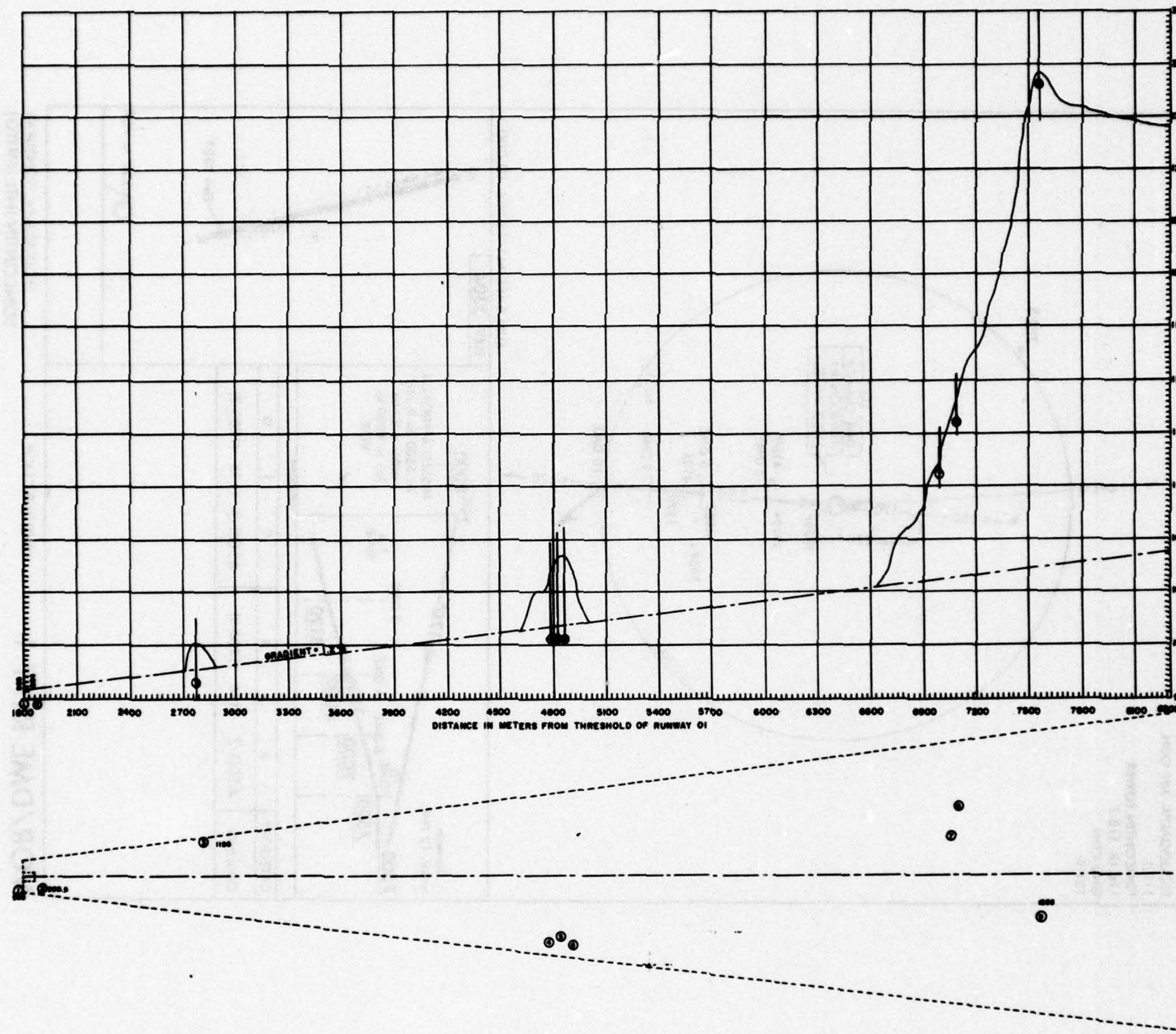


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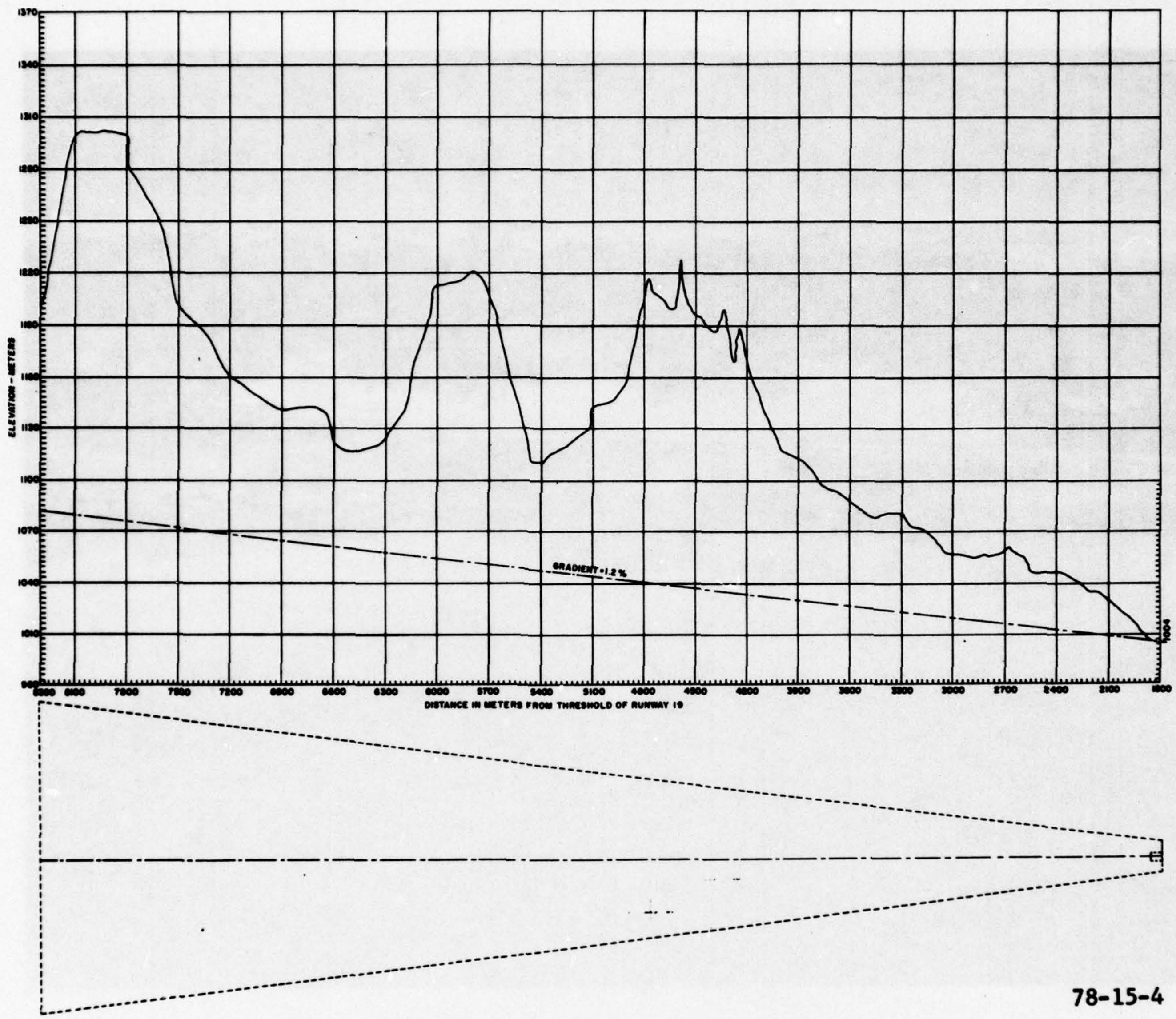
FIGURE 3. ELEVATION PROFILE FOR APPROACH TO R/W 01



78-15-4

FIGURE 4. ELEVATION PROFILE FOR APPROACH TO R/W 19

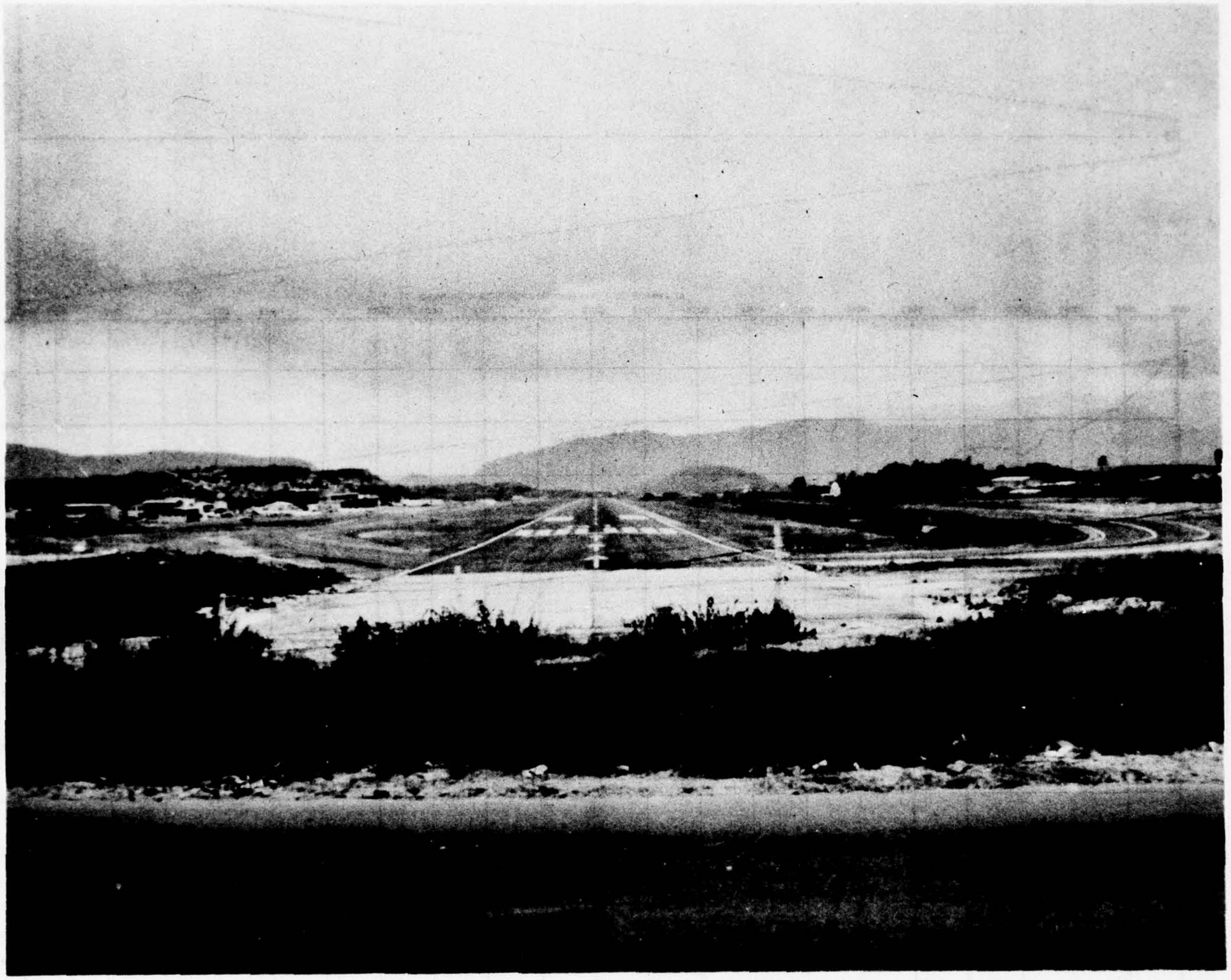


FIGURE 5. VIEW TOWARD APPROACH END OF R/W 19

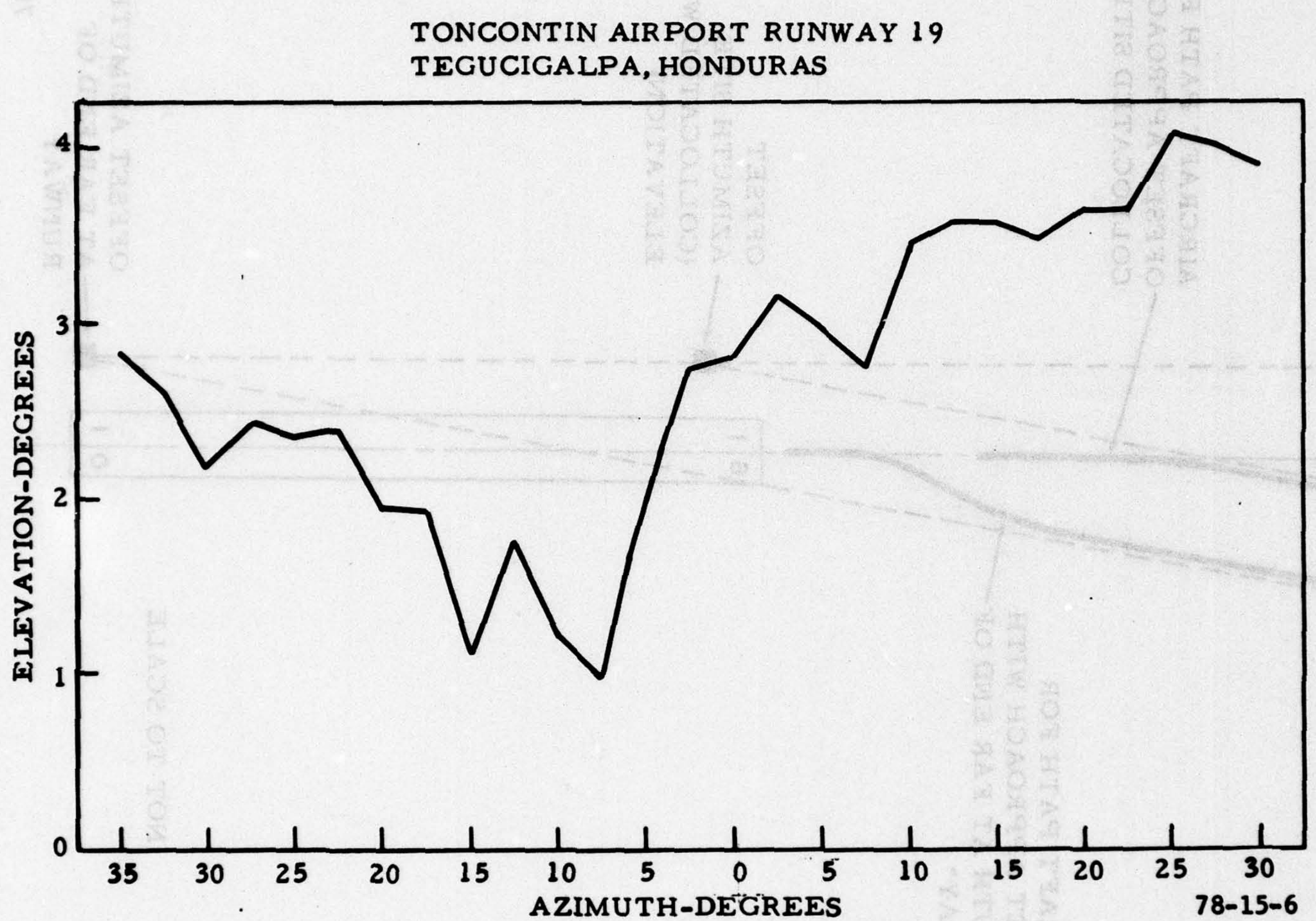


FIGURE 6. TERRAIN CLEARANCE ANGLES FOR APPROACH TO R/W 19

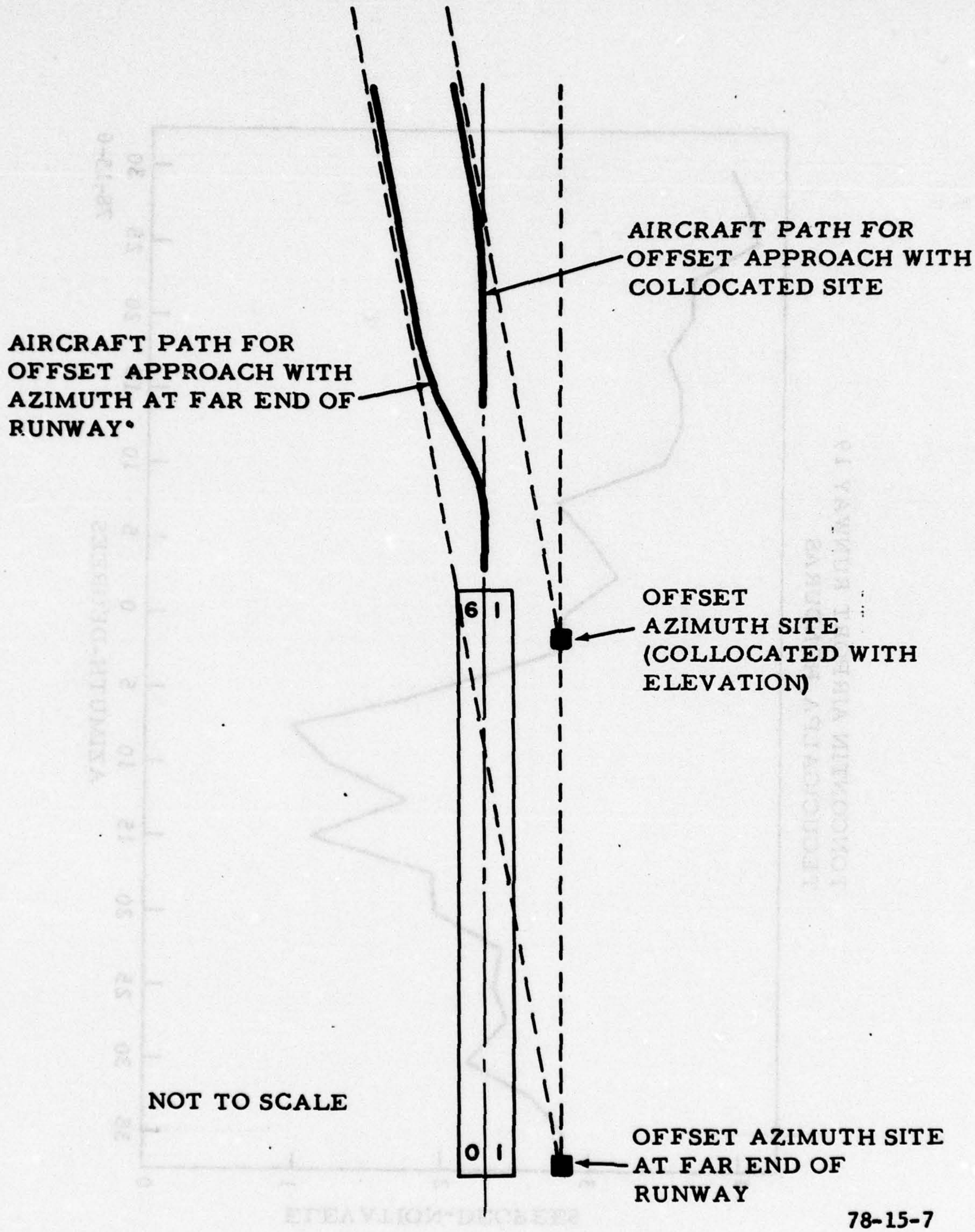


FIGURE 7. AIRCRAFT MANEUVER REQUIREMENTS FOR TWO AZIMUTH OFFSET TYPES

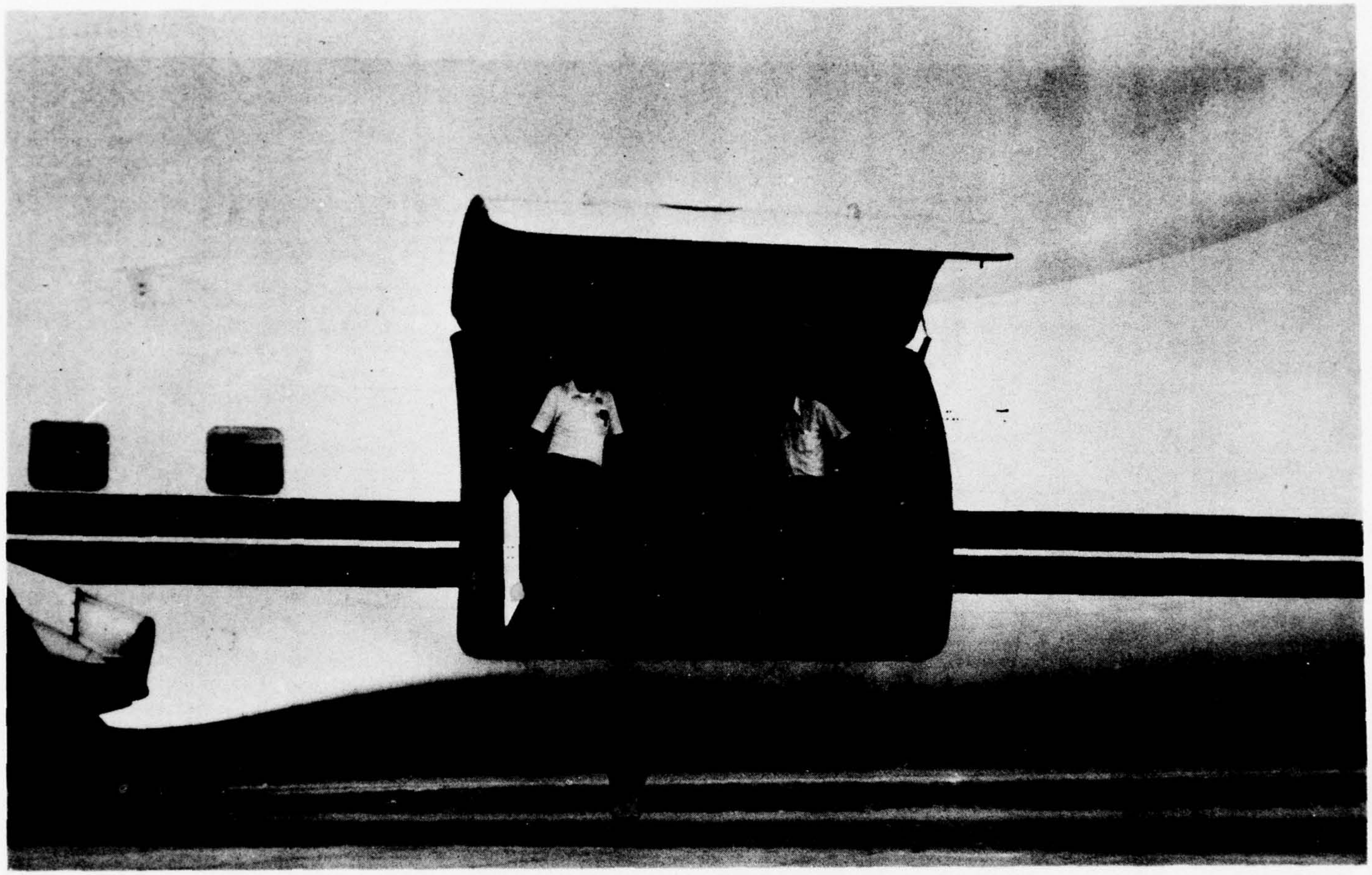


FIGURE 8. EQUIPMENT ARRIVING BY AIR

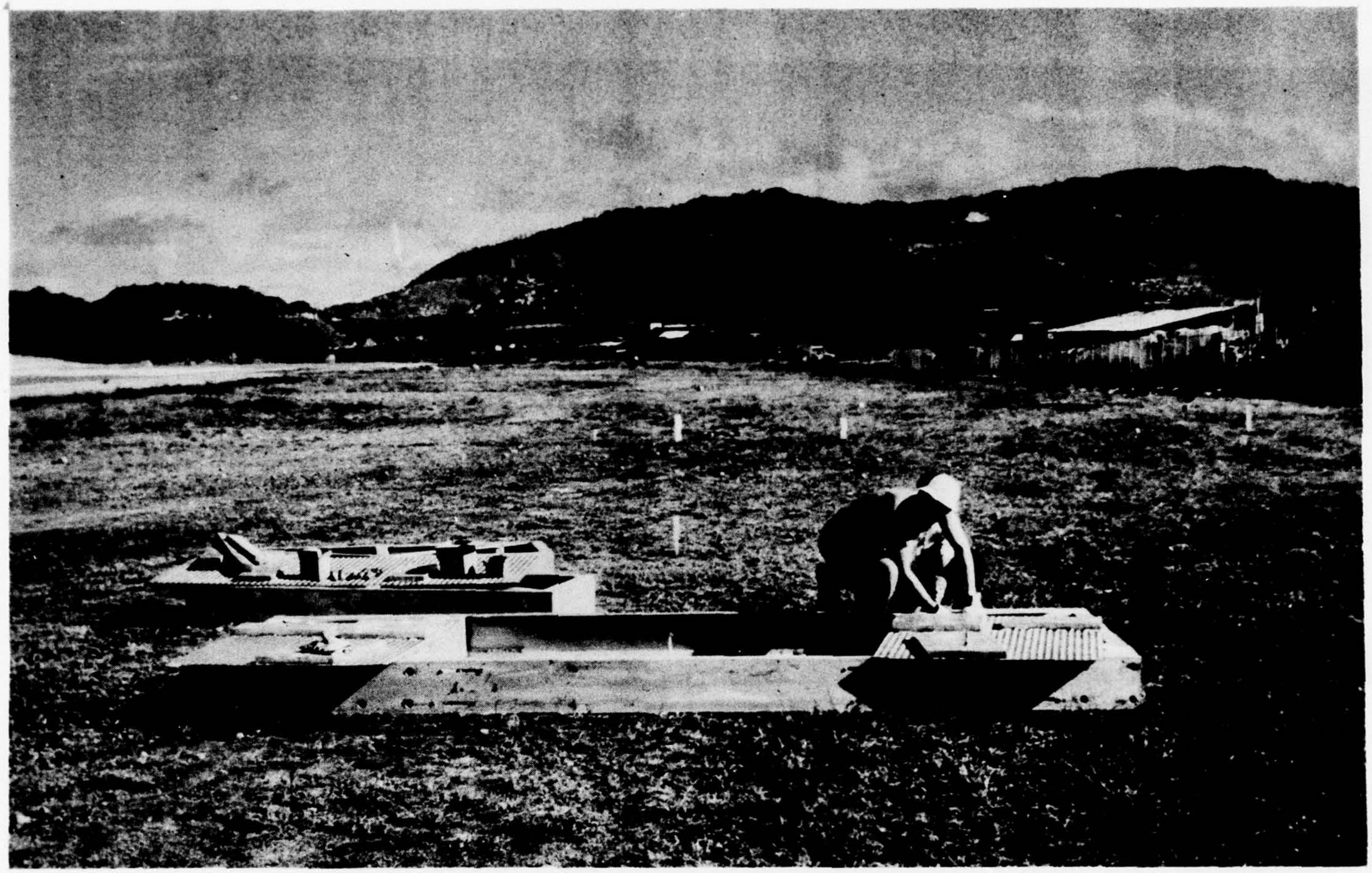


FIGURE 9. TRSB MOUNTING PLATES

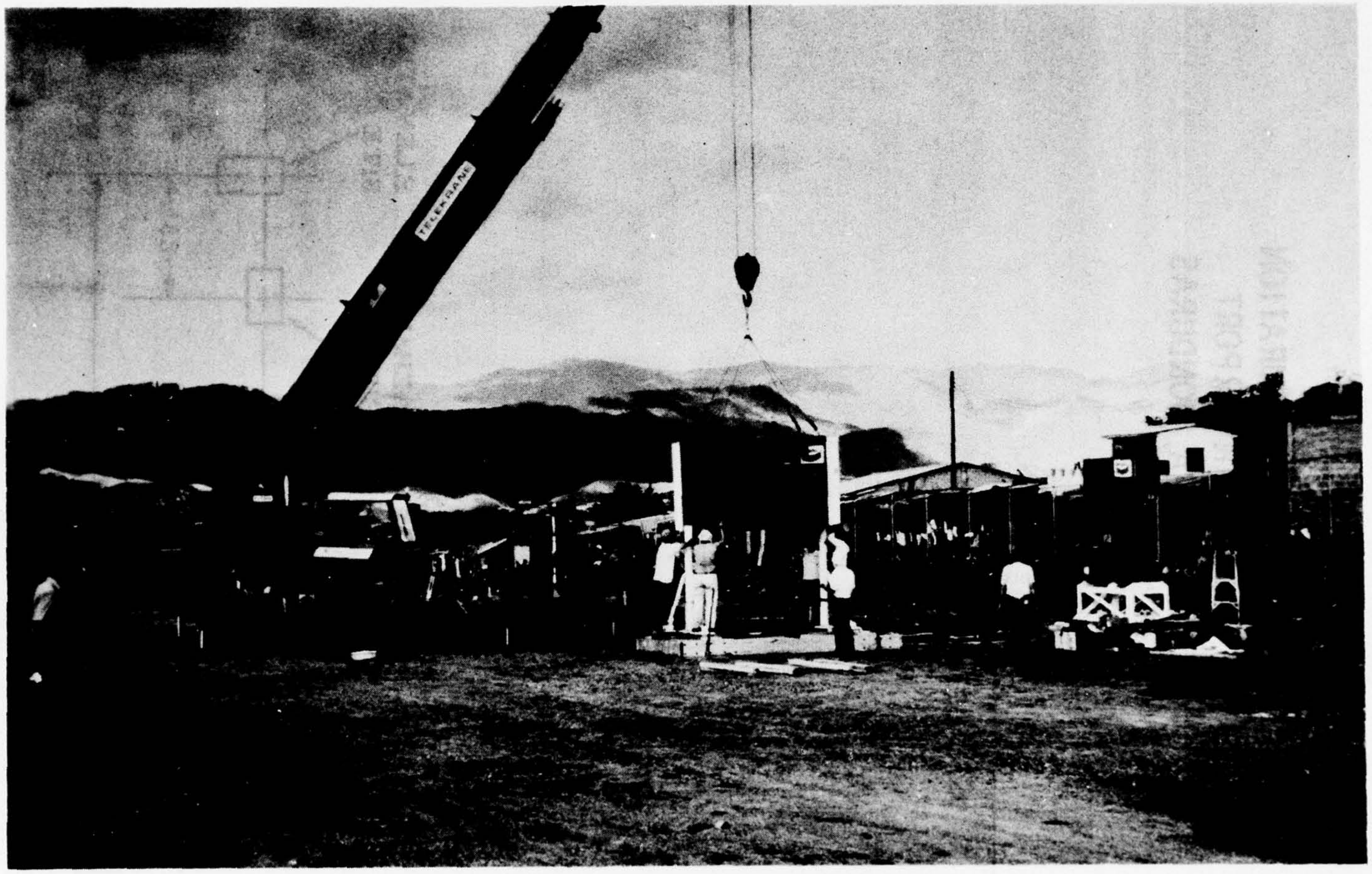


FIGURE 10. TRSB INSTALLATION PROCESS

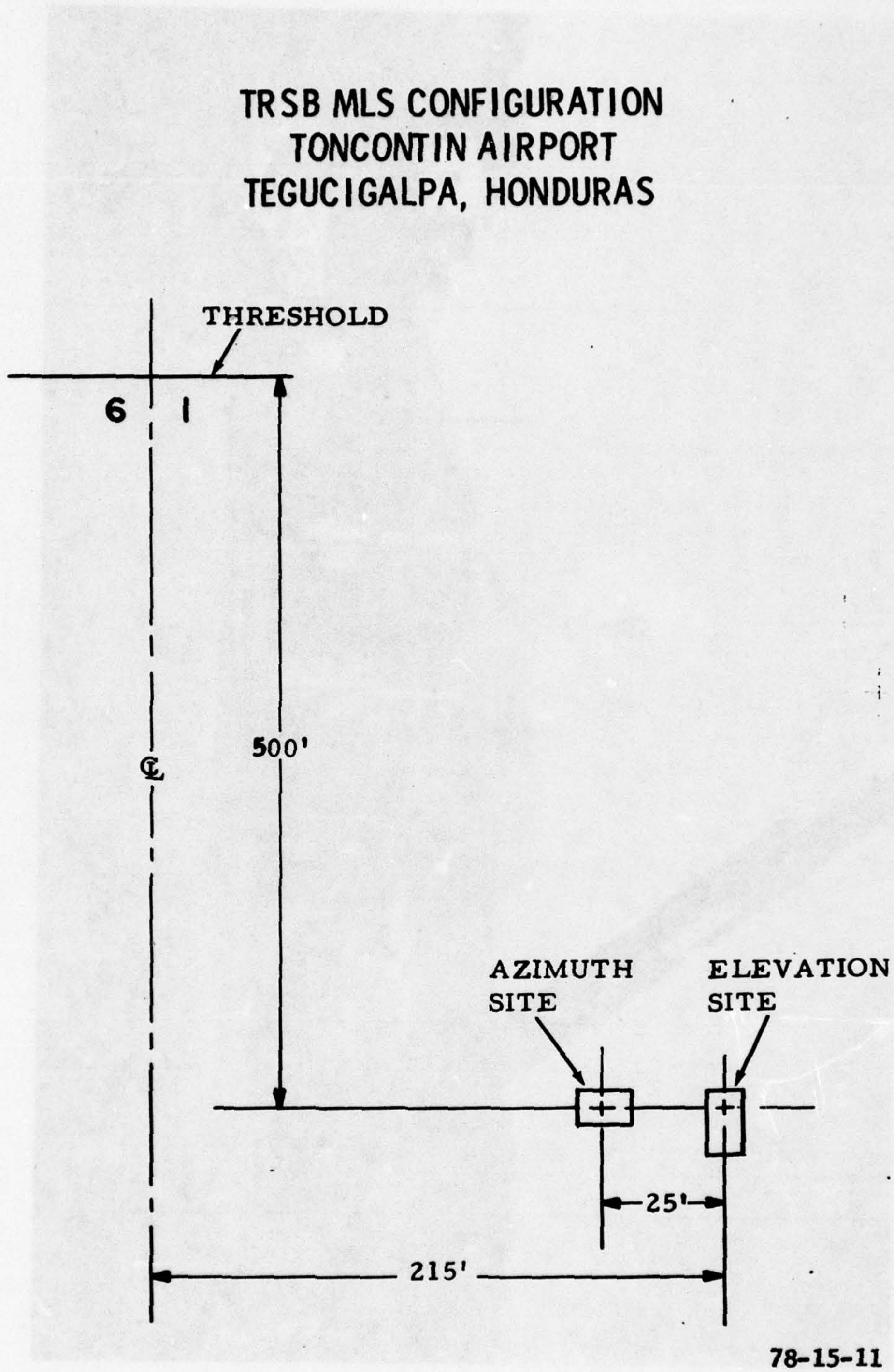


FIGURE 11. TRSB CO-LOCATION DIAGRAM

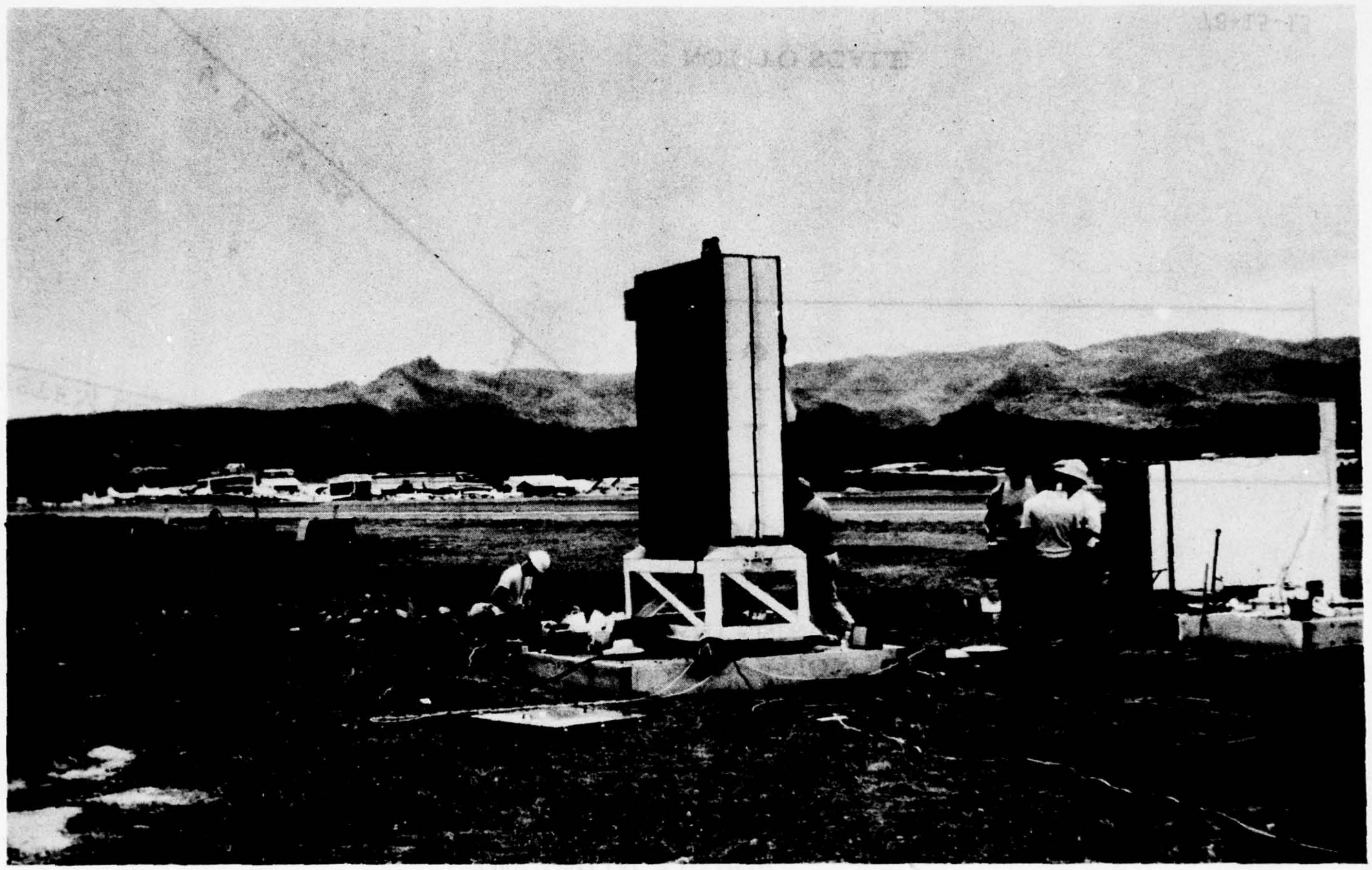


FIGURE 12. ELEVATION AND AZIMUTH TRSB SUBSYSTEMS

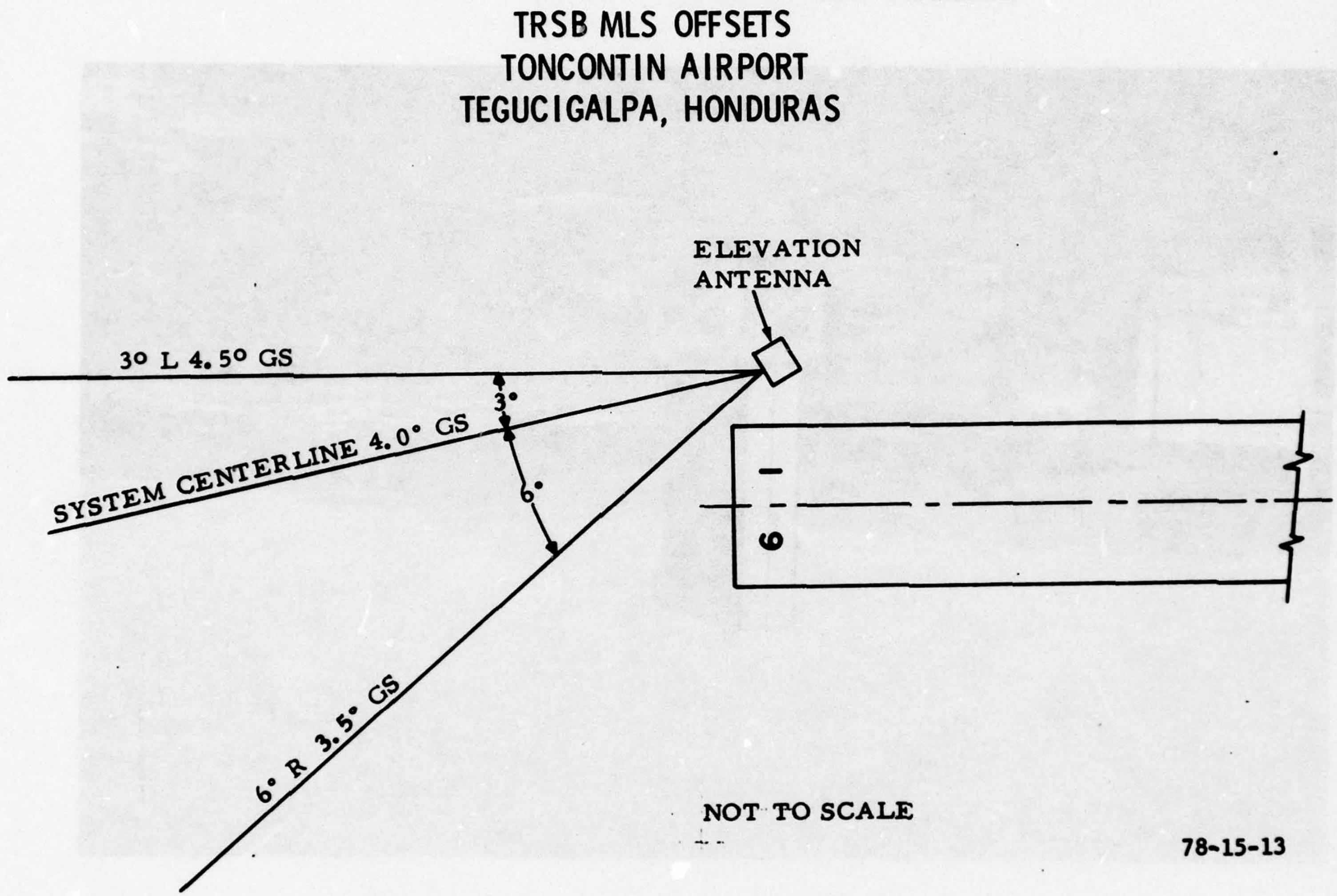


FIGURE 13. TRSB MLS OFFSET

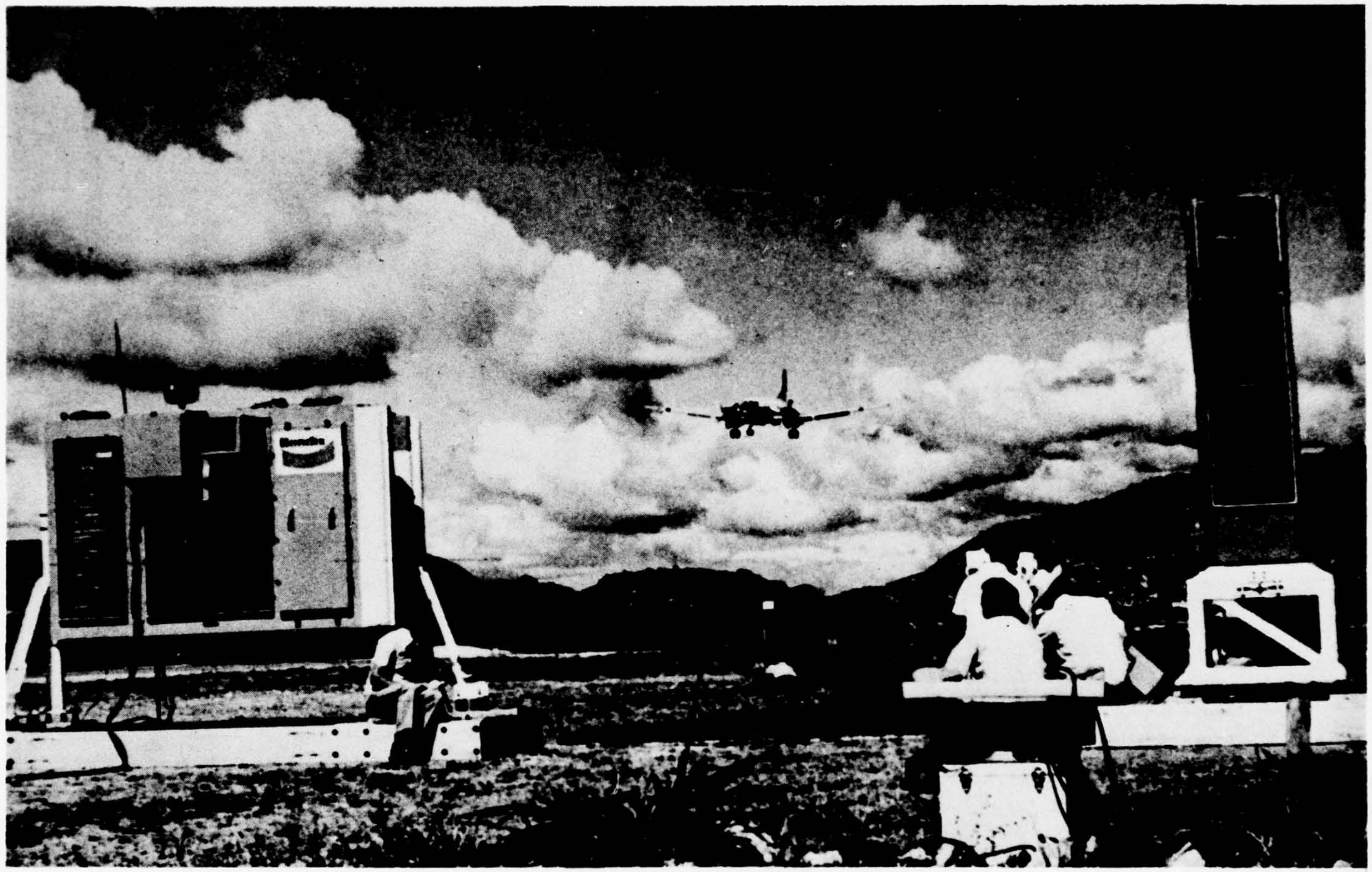
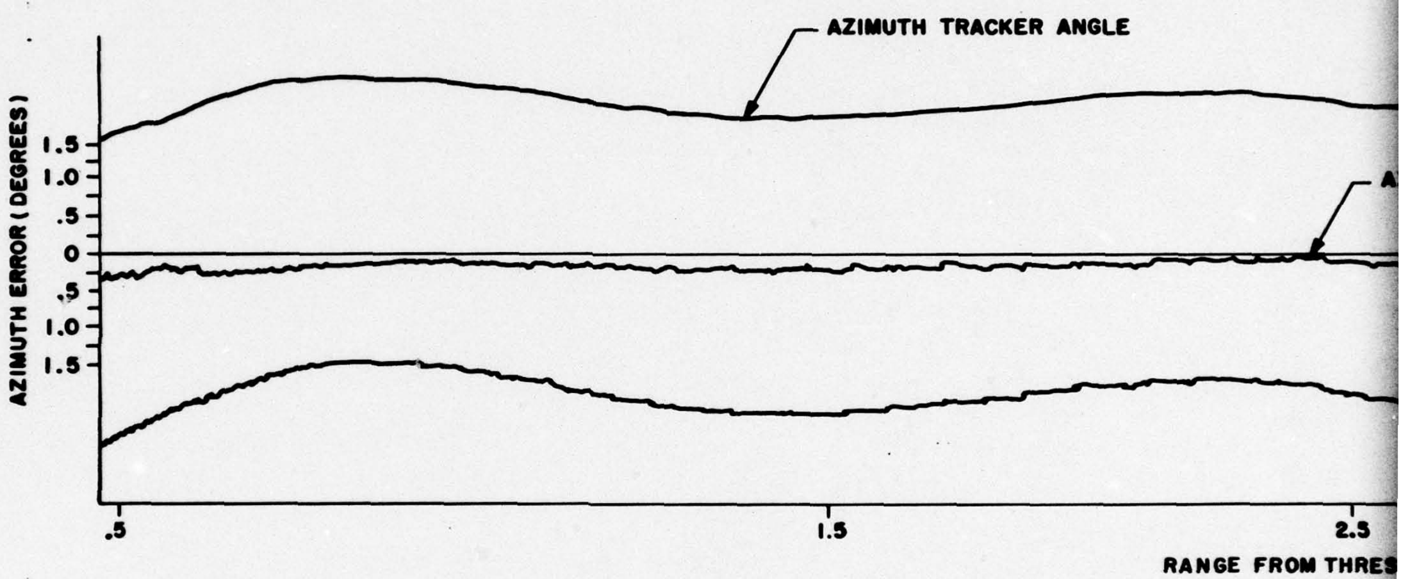


FIGURE 14. TYPICAL TRSB TRACKED APPROACH


AZIMUTH TRACKER ANGLE
AZIMUTH ERROR (DEGREES)
1.5
1.0
.5
0
.5
1.0
1.5
.5
1.5
2.5
RANGE FROM THRES

FIGURE

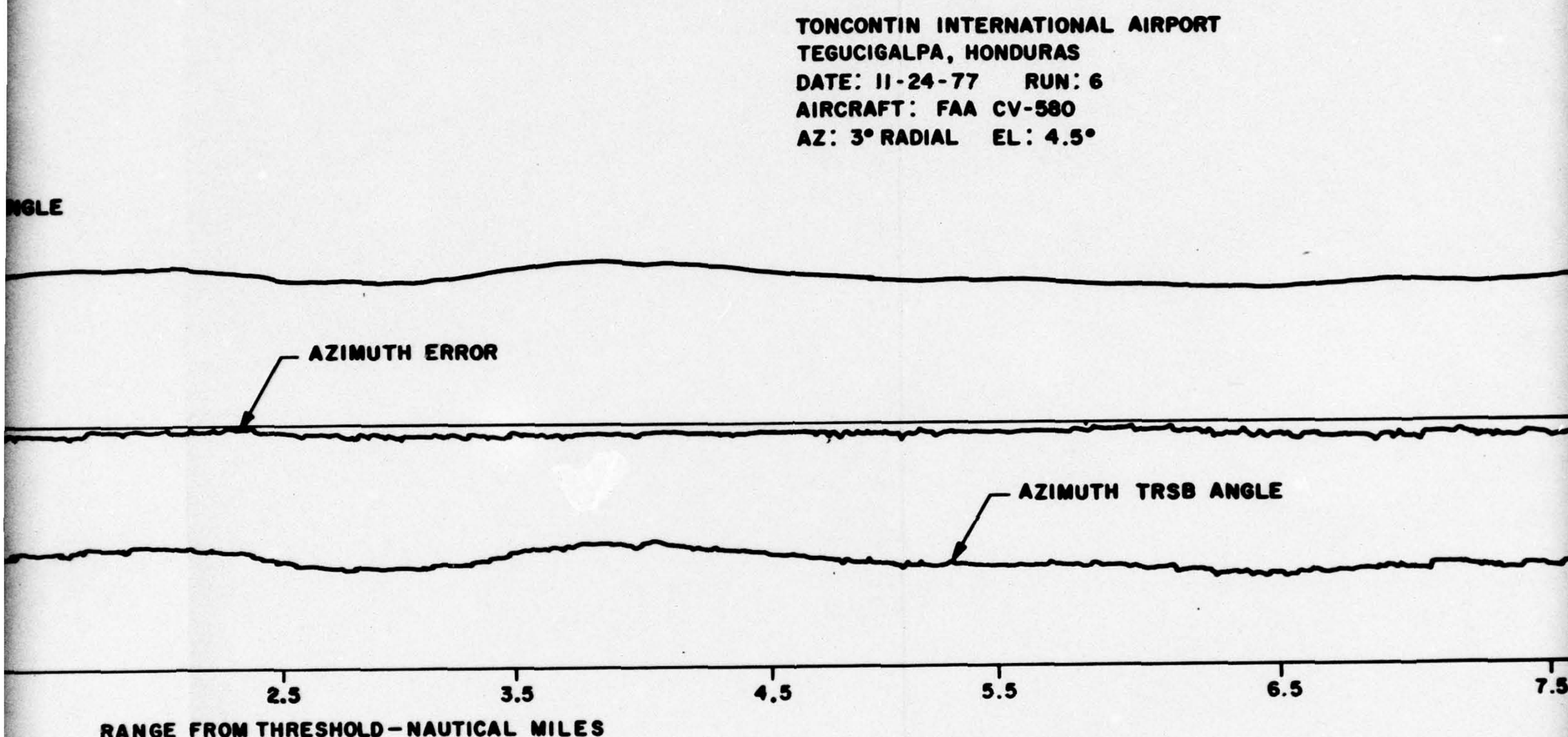


FIGURE 15. SAMPLE AZIMUTH STRIP CHART RECORDING FOR 11-24-77

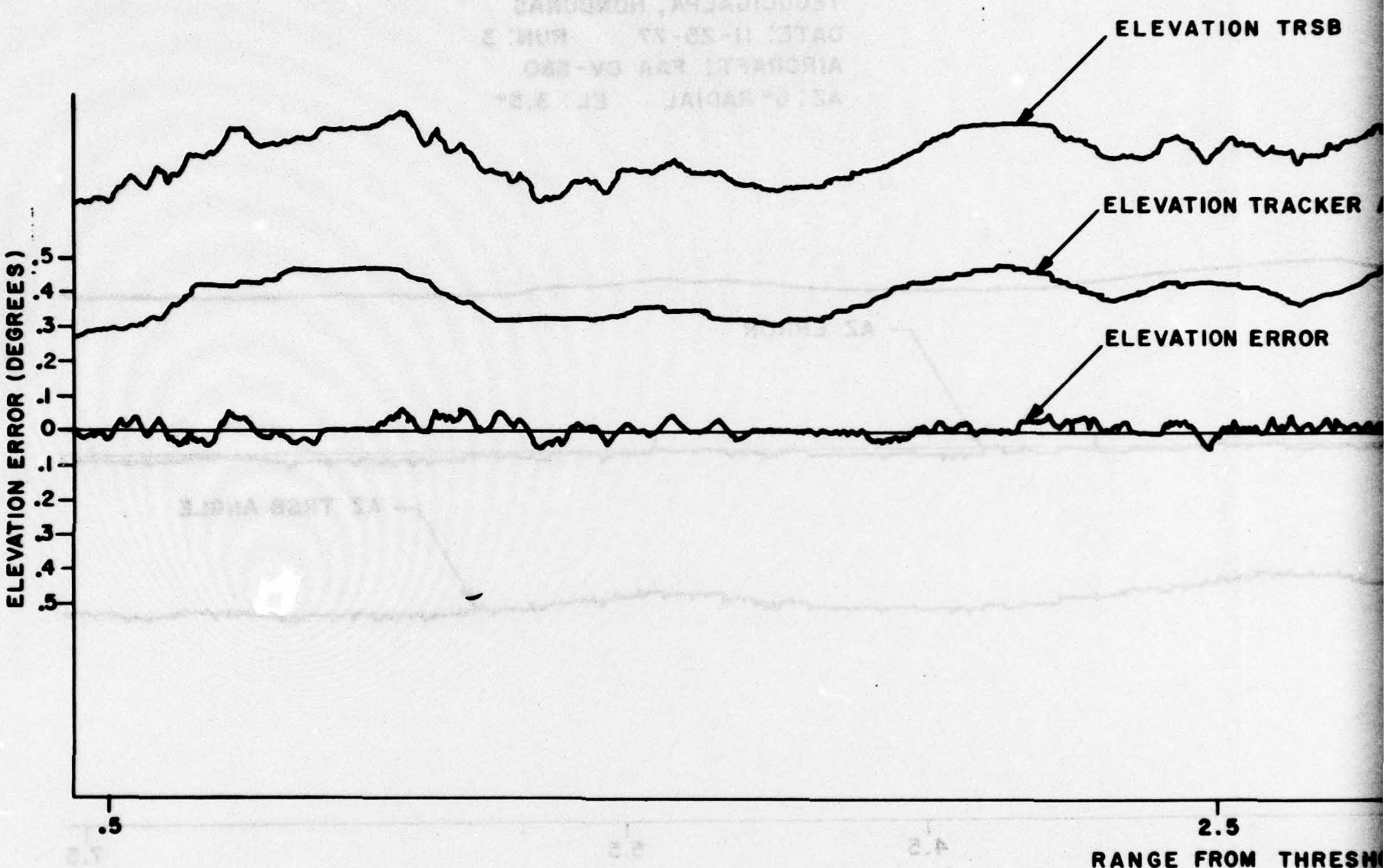
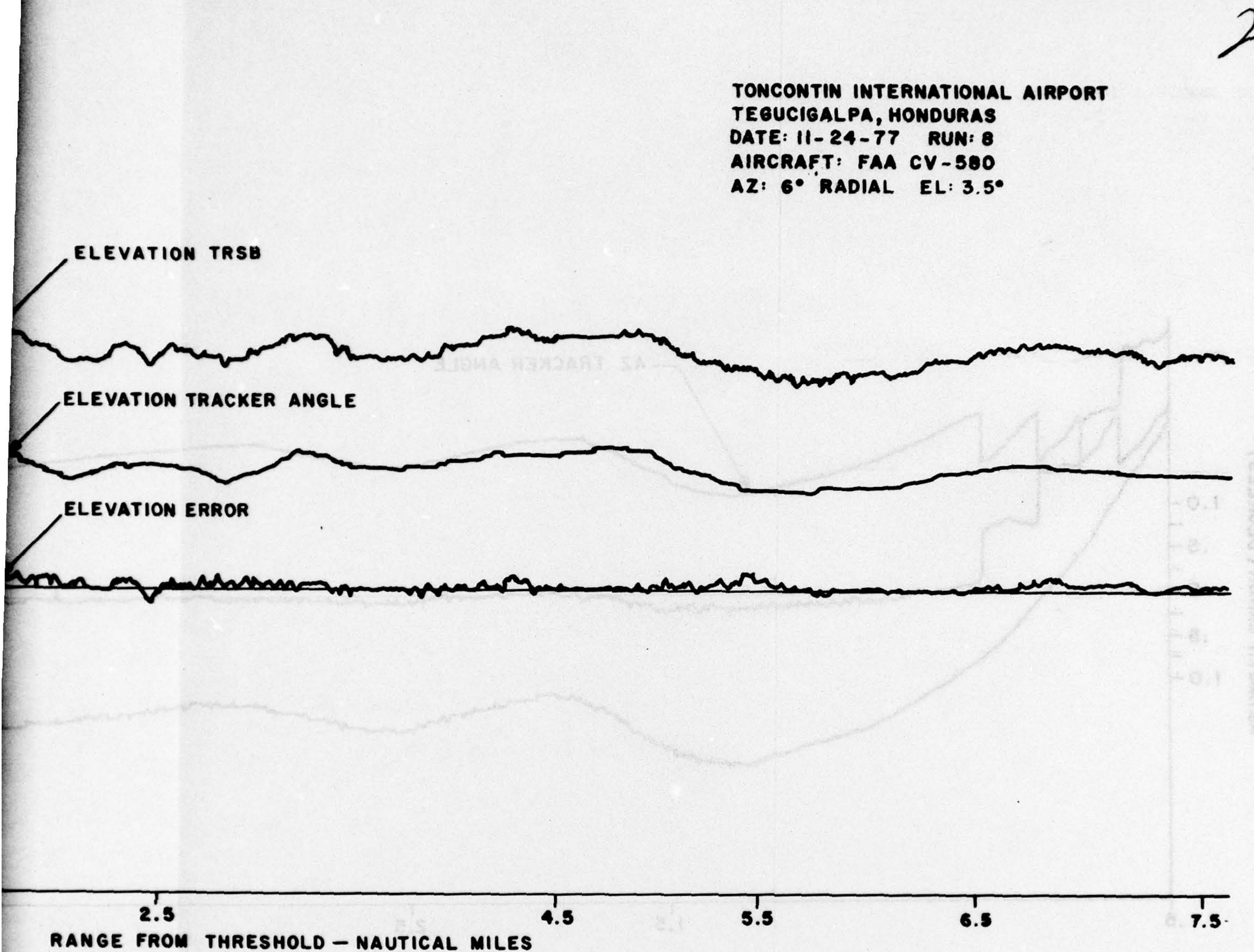
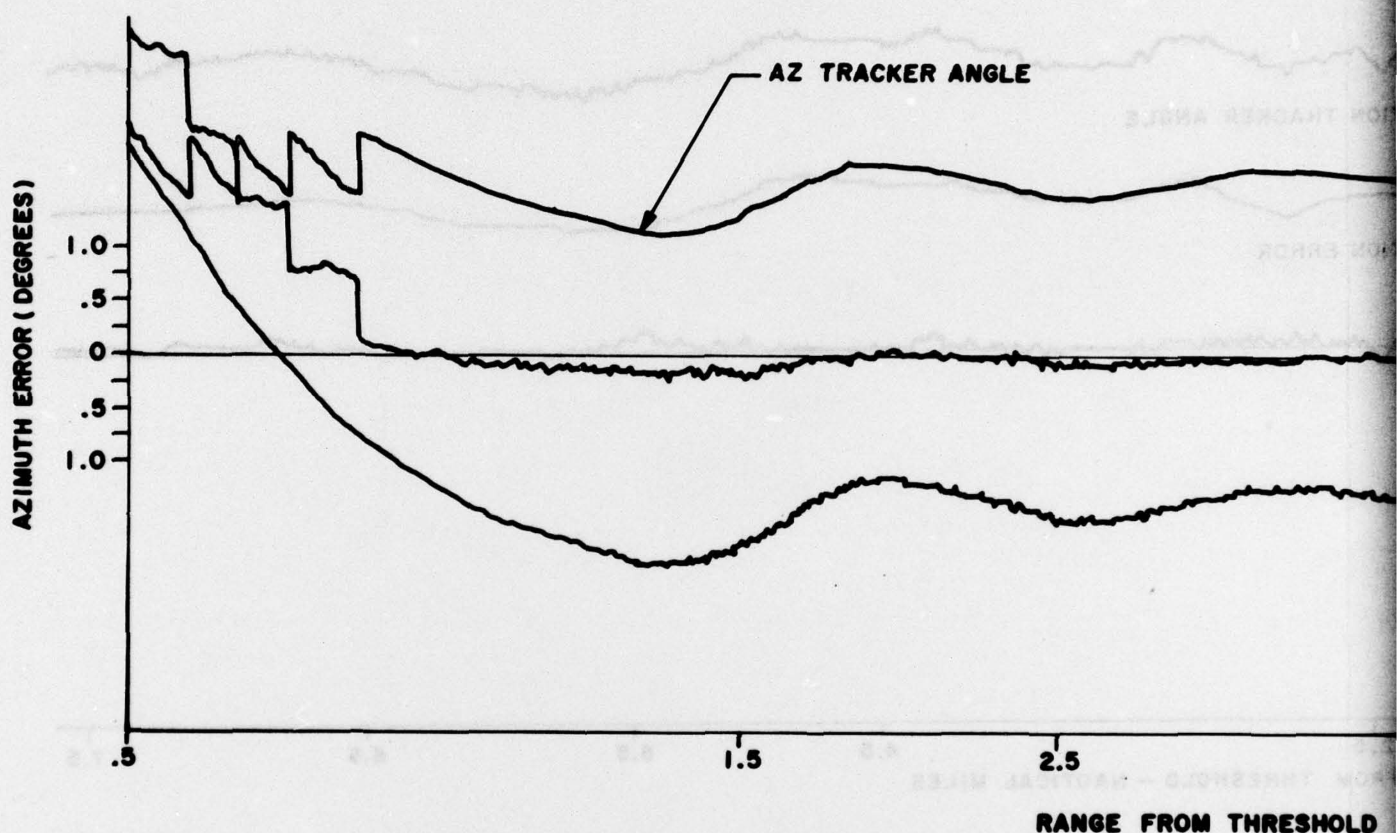

ELEVATION TRSB
ELEVATION TRACKER
ELEVATION ERROR
ELEVATION ERROR (DEGREES)
.5
.4
.3
.2
.1
0
.1
.2
.3
.4
.5
.5
2.5
RANGE FROM THRESH

FIGURE 16



78-15-16

FIGURE 16. SAMPLE ELEVATION STRIP CHART RECORDING FOR 11-24-77


AZ TRACKER ANGLE
AZIMUTH ERROR (DEGREES)
1.0
.5
0
.5
1.0
.5
1.5
2.5
RANGE FROM THRESHOLD

FIGU

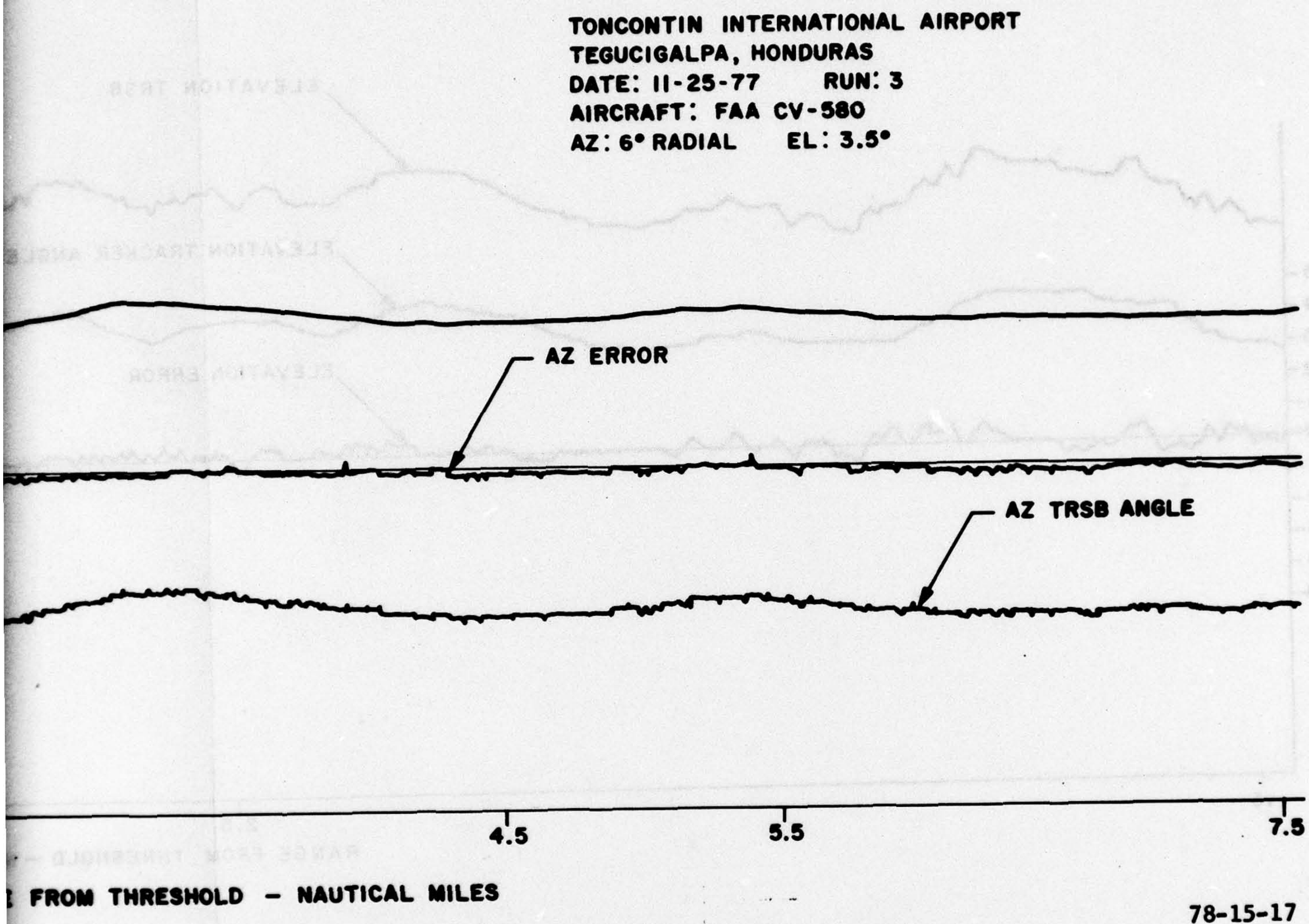
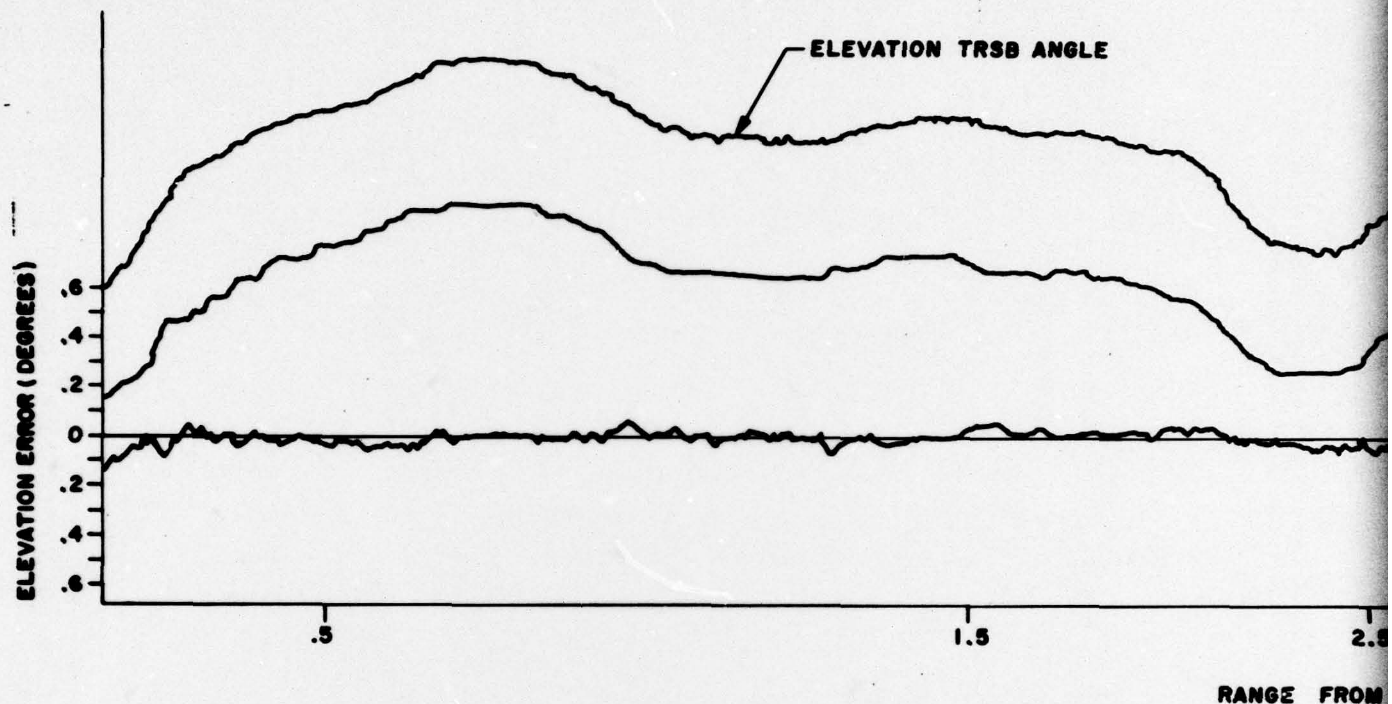


FIGURE 17. SAMPLE AZIMUTH STRIP CHART RECORDING FOR 11-25-77


ELEVATION TRSB ANGLE
ELEVATION ERROR (DEGREES)
.6
.4
.2
0
.2
.4
.6
.5
1.5
2.5
RANGE FROM

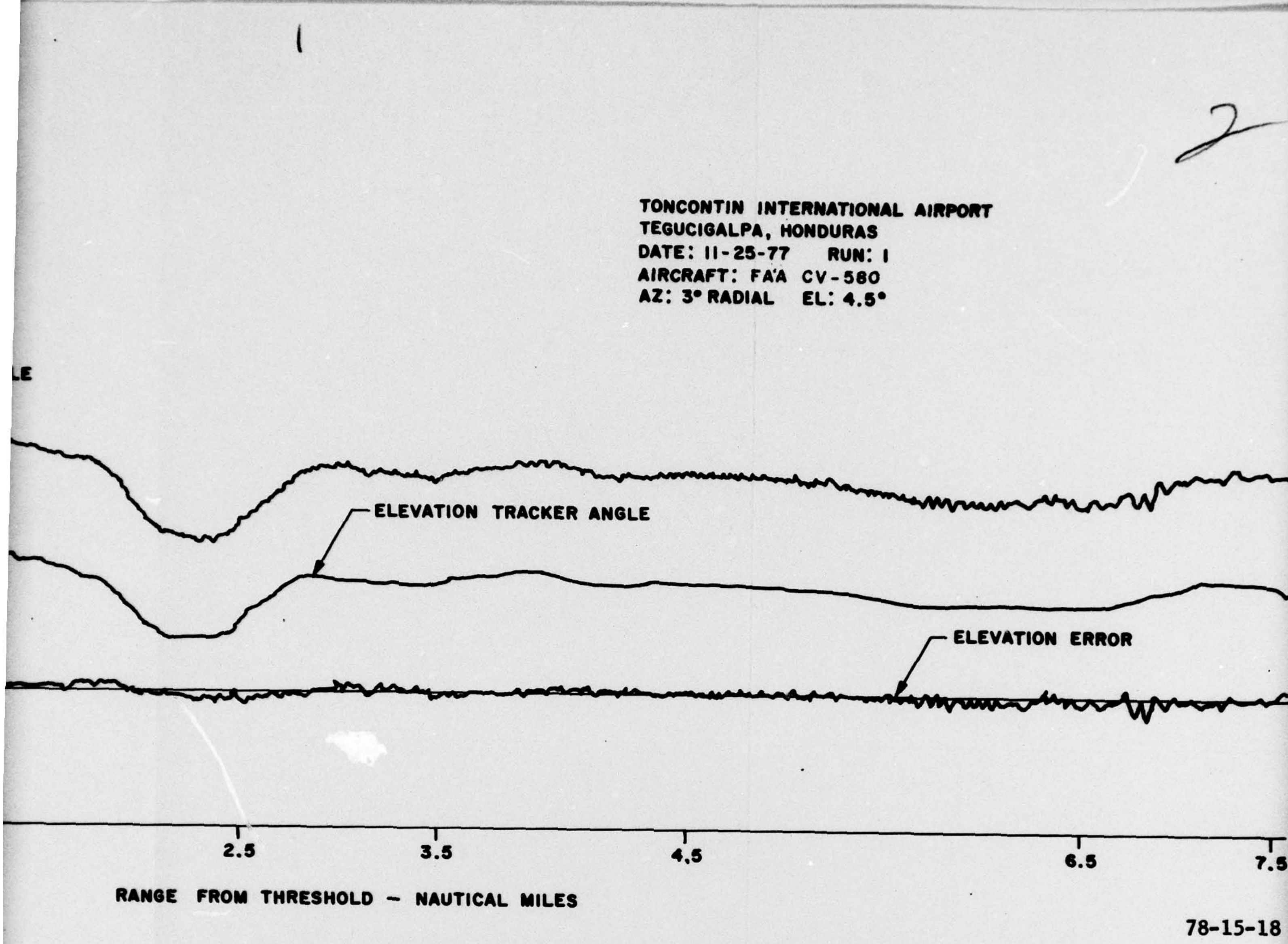


FIGURE 18. SAMPLE ELEVATION STRIP CHART RECORDING FOR 11-25-77

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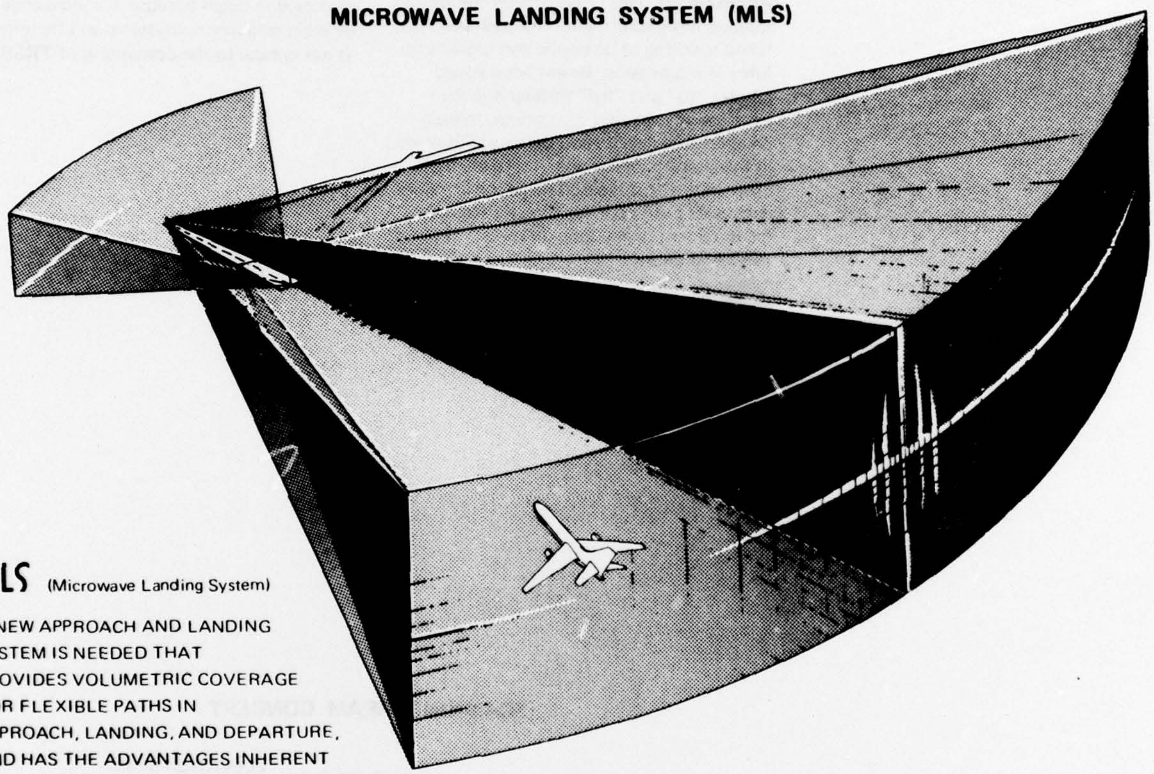
APPENDIX A

MICROWAVE LANDING SYSTEM (MLS)



MLS (Microwave Landing System)

A NEW APPROACH AND LANDING SYSTEM IS NEEDED THAT PROVIDES VOLUMETRIC COVERAGE FOR FLEXIBLE PATHS IN APPROACH, LANDING, AND DEPARTURE, AND HAS THE ADVANTAGES INHERENT WITH OPERATING AT MICROWAVE FREQUENCIES

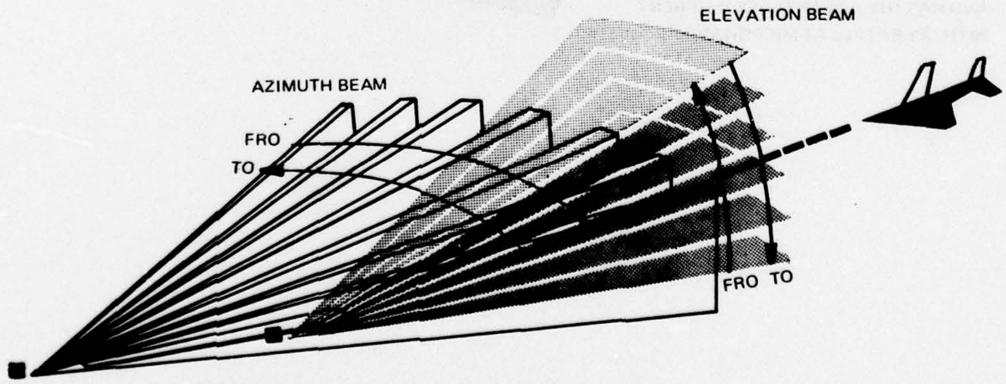
TIME REFERENCE SCANNING BEAM (TRSB) MLS IS AN AIR-DERIVED APPROACH AND LANDING SYSTEM. An aircraft can determine its position in space by making two angle measurements and a range measurement. A simple ground-to-air data capability provides airport and runway identification and other operational data (such as wind speed and direction, site data, and system status).

FAN BEAMS PROVIDE ALL ANGLE GUIDANCE (APPROACH AZIMUTH, ELEVATION, FLARE, AND MISSED APPROACH). The TRSB ground transmitter supplies angle information through precisely timed scanning of its beams and requires no form of modulation. Beams are scanned rapidly "to" and "fro" throughout the coverage volume as shown below. In each complete scan cycle, two pulses are received in the aircraft—one in the "to" scan, the other in the "fro" scan. The aircraft receiver derives its position angle directly from the measurement of the time difference between these two pulses.

RANGE IS COMPUTED IN THE CONVENTIONAL MANNER. TRSB proposes to use L-Band Distance Measuring Equipment (DME) that is compatible with existing navigation equipment. It provides improved accuracy and channelization capabilities. The required 200 channels can be made available by assignment or sharing of existing channels, using additional pulse multiplexing. The ground transponder is typically collocated with the approach azimuth subsystem.

NOTE: The DME (ranging) function is not discussed in detail because it is independent of angle guidance subsystems and therefore **is not critical to the description of TRSB.**

SCANNING BEAM CONCEPT



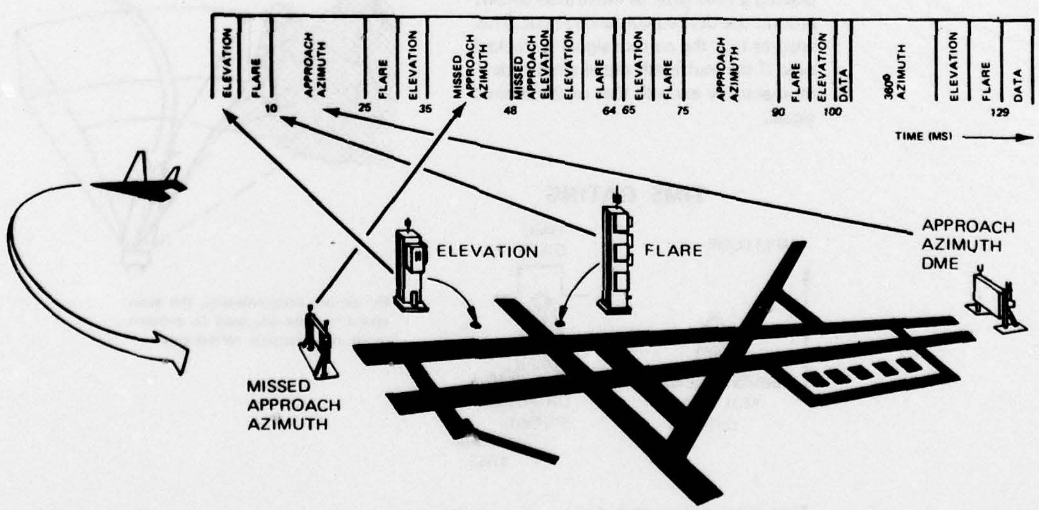
TRSB beams are scanned rapidly "to" and "fro" (back and forth for azimuth, down and up for elevation) at a precise rate

TRSB USES A TIME-SEQUENCED SIGNAL FORMAT FOR ANGLE AND DATA FUNCTIONS. Angle and data functions (that is, approach azimuth, elevation, flare, missed-approach guidance, and auxiliary data) are sequentially transmitted by the ground station on the same channel. Primary operation is C-band, with 300 KHz spacing between channels. However the format is compatible with Ku-Band requirements. (Note: DME is an independent function on a separate frequency and is not a part of this format.)

THE SIGNAL FORMAT IS DESIGNED TO ALLOW A MAXIMUM DEGREE OF FLEXIBILITY. Functions can be transmitted in any order or combination to meet the unique operational needs of each site. This flexibility is made possible by a function preamble identification message. This message sets the airborne receiver to measure the angle or decode the data function that will follow. The ordering or timing of transmissions, therefore, is not important. This flexibility permits individual functions to be added or deleted to meet specific airport requirements. It also permits any TRSB airborne receiver to operate with any ground system. The only requirements are that a minimum data rate (minimum number of to-fro time-difference measurements per second) be maintained for each angle function, and that these measurements be relatively evenly distributed in time. An example of two 64-millisecond sequences of a configuration that utilizes all available functions is illustrated below.

THE TRSB FORMAT PROVIDES FOR CURRENT AND ANTICIPATED FUTURE REQUIREMENTS. Included are

- Proportional azimuth angle guidance to ±60° relative to runway centerline at a 13.5-Hz update rate (that is, data are renewed 13.5 times each second.)
- Proportional missed-approach azimuth guidance to ±40° relative to runway centerline at a 6.75-Hz update rate
- Proportional elevation guidance up to 30° with a 40.5-Hz update rate
- Flare guidance up to 15° with a 40.5-Hz update rate
- 360° azimuth guidance with a 6.75-Hz update rate
- Missed-approach or departure elevation function with a 6.75-Hz update rate
- Basic data prior to each angle function (includes function identification, airport identification, azimuth scale factors, and nominal and/or minimum selectable glide slope)
- Auxiliary data (for example, environmental and airport conditions)
- Facility status data
- Ground test signals
- Available time for other data and/or additional future functions.

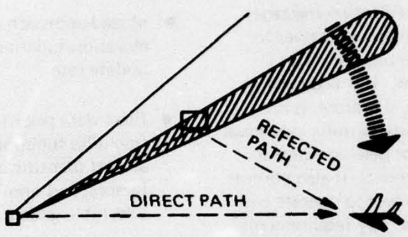


The TRSB signal offers maximum flexibility to meet unique user requirements

TRSB OPERATES EFFECTIVELY IN SEVERE MULTIPATH ENVIRONMENTS. TRSB offers several unique solutions to the multipath problem that has limited the implementation of other landing systems.

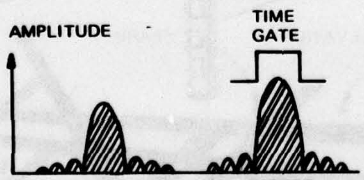
THERE ARE TWO TYPES OF MULTI-PATH. Multipath occurs when a microwave signal is reflected from a surface, such as an airport structure, a vehicle, and certain types of terrain. The resulting reflected beam is classified as either out-of-beam multipath or in-beam multipath, depending on its time of arrival in the aircraft receiver relative to the direct signal.

REFLECTED SIGNALS



OUT-OF-BEAM MULTIPATH. If the angle and therefore the time between the reflected and direct beam are relatively large, the aircraft receiver is subjected to out-of-beam multipath. In this case, the TRSB processor automatically rejects the reflected signal by placing a time gate, as illustrated below, *around the desired guidance signal.* This ensures that the correct signal is tracked even if the multipath signal amplitude momentarily exceeds that of the desired signal.

TIME GATING



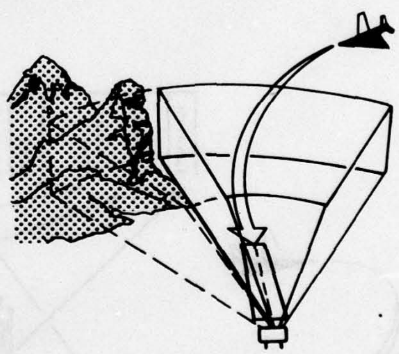
Time gating ensures that the correct signal is tracked, not the reflected one

IN-BEAM MULTIPATH. When the reflected and direct signals reach the aircraft almost simultaneously (the angle of arrival is very small), multipath is said to be in-beam. TRSB combats in-beam multipath by

- Shaping the horizontal pattern of the elevation antenna to reject lateral reflections
- Motion averaging, by utilizing the high data rates of TRSB
- Processing only the leading edge of the flare/elevation beam, which is not contaminated by the ground reflections.

COVERAGE CONTROL IS AVAILABLE TO ELIMINATE MULTIPATH AT EXTREMELY SEVERE PROBLEM SITES. Any MLS system will experience acquisition or tracking problems in those cases where the reflected signal is known to be persistent and greater in amplitude than the direct signal. A TRSB feature called coverage control can be implemented, at no cost, in such cases by simply programming the Beam Steering Unit (BSU). This feature permits a simple adjustment of the ground facility to limit the scan sector in the direction of the obstacle and thereby prevents acquisition of erroneous signals.

SELECTIVE COVERAGE CONTROL



By simple programming, the scan sector can be adjusted to prevent undesired obstacle reflections

TRSB IS A MODULAR SYSTEM WHICH CAN BE CONFIGURED TO MATCH THE NEEDS OF THE USER. A set of phased-array subsystems has been designed that may be installed in any combination to meet the broad range of user requirements.

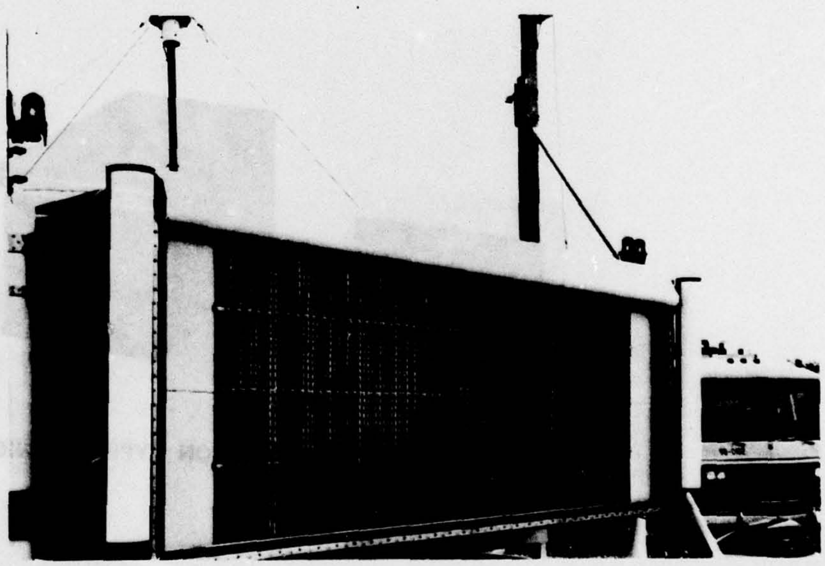
The minimum system configuration consists of approach azimuth and elevation subsystems. Flare, missed-approach, and range subsystems may be included or added later. Several antenna beamwidths are available, as indicated in the table below, from which a ground configuration can be designed to provide guidance signals-in-space of uniform quality in all airport environments.

NOTE: DME is an independent subsystem which is combined with appropriate azimuth and elevation subsystems to make up the total guidance system.

GROUND ANGLE SUBSYSTEMS

SUB-SYSTEM	NOMINAL BEAMWIDTH (DEGREES)	COVERAGE (DEGREES) *	PRINCIPAL APPLICATIONS
Azimuth	1	Up to ± 60	Approach Azimuth; Long Runways
Azimuth	2	Up to ± 60	Approach Azimuth; Intermediate Length Runways
Azimuth	3	Up to ± 60	Approach Azimuth; Short Runways Missed Approach Azimuth
Elevation	0.5	Up to 15	Flare
Elevation	1	Up to 30	Elevation (Severe multipath sites)**
Elevation	2	Up to 30	Elevation (Less severe multipath sites)**

* Coverage determined by Beam Steering Unit (BSU) for all arrays.
** **See multipath discussion.**



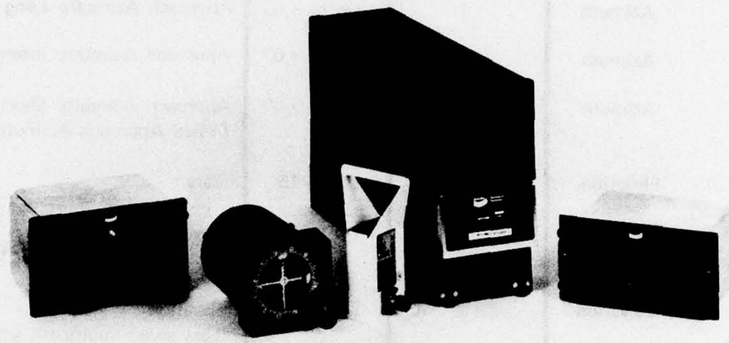
Phased Array Azimuth Antenna installed at the National Aviation Facilities Experimental Center. Radome is rolled back to expose radiating elements.

AIRBORNE RECEIVER DESIGNS ALSO STRESS THE MODULARITY CONCEPT. Users need only procure what is necessary for the services desired from any ground facility. To obtain approach and landing guidance at the lowest cost, an aircraft needs only an antenna and a basic receiver-processor unit operating with existing ILS displays. An air-transport category aircraft equipped for operation to low-weather minimums will carry redundant equipment and, in the future, advanced displays to fully utilize all of the inherent operational capabilities provided by TRSB.

The 200-channel TRSB angle receiver-processor provides angle information from the scanning beam azimuth and elevation subsystems and decodes the auxiliary data for display. Special monitoring ensures the integrity of the receiver output.

A second airborne unit is the DME. It is channeled to operate with the angle receiver-processor and provides a continual readout of distance.

Both the angle receiver-processor and the DME provide standard outputs to existing flight instruments and autopilot systems. An optional airborne computer would be used to generate curved or segmented approaches based on TRSB position information.



AIRLINE TYPE AVIONICS

GENERAL AVIATION TYPE AVIONICS

TRSB CAN PROVIDE ALL-WEATHER LANDING CAPABILITY AT MANY RUNWAYS THAT PRESENTLY DO NOT OFFER THIS SERVICE. This is made possible by

- The proposed channel plan, which contains enough channels for any foreseeable implementation
- High system integrity and precision
- Minimum siting requirements.

THE LARGE COVERAGE VOLUME PROVIDES FLIGHT PATH FLEXIBILITY. Transition from en route navigation is enhanced through the wide proportional coverage of MLS. Such flexibility in approach paths, coupled with high-quality guidance, can be used to achieve

- Improvements in runway and airport arrival capacity
- Better control of noise exposure near airports
- Optimized approach paths for future V/STOL aircraft
- Intercept of glide path and of runway centerline extended without overshoot
- Lower minimums at certain existing airports by providing precise missed-approach guidance
- Wake vortex avoidance flight paths.

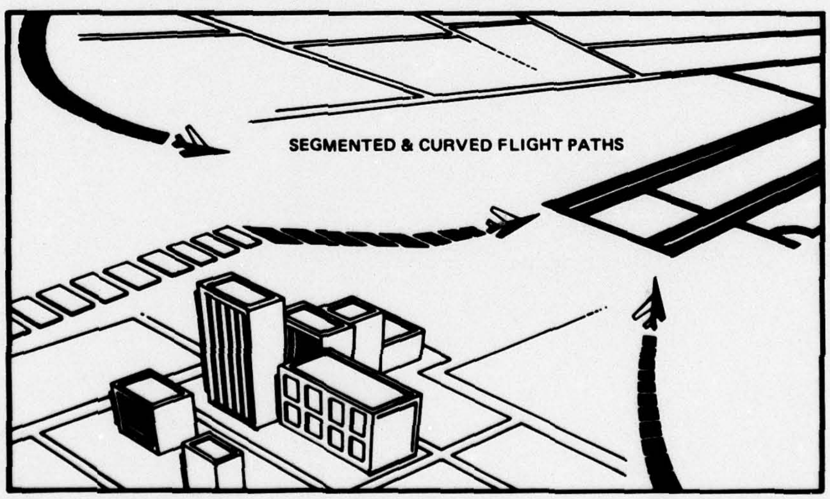
THE TRSB SIGNAL FORMAT ENSURES THAT EVERY AIRBORNE USER MAY RECEIVE LANDING GUIDANCE FROM EVERY GROUND INSTALLATION. Compatibility is ensured between facilities serving international civil aviation and those serving unique national requirements.

TRSB SPANS THE ENTIRE RANGE OF APPROACH AND LANDING OPERATIONS FOR ALL AIRCRAFT TYPES. This includes CTOL, STOL, and VTOL aircraft operating over a wide range of flight profiles. The particular needs of users, ranging from general aviation to major air carriers, are accommodated. TRSB is adaptable to special military applications, such as transportable or shipboard configurations on a compatible basis with civil systems.

HIGH RELIABILITY, INTEGRITY, AND SAFETY OF TRSB ARE ENHANCED BY SEVERAL IMPORTANT FEATURES. These include

- Simple TRSB receiver processing
- Multipath immunity features on the ground and in the airborne receiver-processor
- A comprehensive monitoring system that verifies the status of all subsystems and the radiated signal. Status data are transmitted to all aircraft six times each second.
- Coding features, such as parity and symmetry checks, that prevent the mixing of functions.

TRSB PROVIDES CATEGORY-III QUALITY GUIDANCE. TRSB signal guidance quality has already been proved via demonstration of fully automatic landings, including rollout, in a current commercial transport aircraft (Boeing 737) and an executive jet (North American Sabreliner).



TRSB provides precision guidance for curved and segmented approaches for noise abatement and traffic separation, as well as for autoland and rollout